1.0 INTRODUCTION

1.1 PURPOSE AND OBJECTIVES

This Expanded Engineering Evaluation/Cost Analysis (EEE/CA) was prepared for the Montana Department of Environmental Quality/Mine Waste Cleanup Bureau (DEQ/MWCB) by Pioneer Technical Services, Inc. (Pioneer), under the Engineering Services Agreement 470024, Task Order No. 23.

The primary purpose of this report is to present the detailed analysis of reclamation alternatives in accordance with the National Contingency Plan (NCP). In addition, the site background, waste characteristics, applicable or relevant and appropriate requirements (ARARs), risk assessment, and the development and screening of alternatives are presented herein. The purpose for providing this supplemental information with the detailed analysis of reclamation alternatives is to give the reviewers and risk managers a single comprehensive, "stand-alone" decision making tool.

The Frohner Mine Site (PA#22-243) is an abandoned hardrock mine/millsite ranked No. 61 on the DEQ/MWCB Priority Sites List (including both the mine site and the on-site mill tailings). The general location of the Frohner Mine Site is 15 miles southwest of Helena, Montana, in Jefferson County, as shown on Figure 1-1. The Frohner Mine Site is located in Sections 14 and 15 of Township 8 North, Range 5 West of the Montana Principle Meridian and is within the historic Clancy Mining District.

The Frohner Mine Site consists of seven waste rock dumps, one mill tailings pile, numerous streamside tailings deposits (SST), and two discharging adits, in addition to a small perennial stream (Frohner Meadows Creek) which flows adjacent to the lower portion of the site. Portions of the site lie in patented claims within the Helena National Forest; however, some of the wastes are located on unpatented claims on U.S. Department of Agriculture/Forest Service (USFS) property. The topography in the area is mountainous with elevations at the site ranging from approximately 7,200 to 7,400 feet.

Adjacent to the Frohner Mine Site are both the Nellie Grant (PA#22-244) and the General Grant (PA#22-245) mine sites which are located within one mile to the east of the Frohner Mine Site. The Nellie Grant Mine Reclamation Project took place during the 1998 construction season and was conducted by DEQ/MWCB. The project was an extension of previous reclamation activities, which took place at the Nellie Grant Mine on two separate occasions, first from 1981 to 1983, and again in 1993.

Frohner Meadows Creek is a tributary to Lump Gulch, which is a tributary to Prickly Pear Creek, which in turn flows north through the Helena Valley to the Missouri River.

Additional information regarding the site is available in the following documents: the 1995 DEQ/MWCB Abandoned Mine Hazardous Materials Inventory Form (DEQ/MWCB-Pioneer, 1995), the Reclamation Work Plan for the Frohner Mine Site (DEQ/MWCB-Pioneer, 1998a), the Final Adit Baseline Characterization Investigation Report (DEQ/MWCB-Pioneer, 1998b), and the Field Sampling Plan for the Frohner Mine Site Removal Action Investigation (DEQ/MWCB-Pioneer, 1999a).

1.2 REPORT ORGANIZATION

This report is organized into 11 sections. The contents of the remaining sections are briefly described in the following paragraphs.

SECTION 2.0 BACKGROUND - presents a background description of the Frohner Mine Site. Significant site features; a detailed history of past mining and milling activities; geologic, hydrologic, and climatic characteristics of the site; the biological setting, such as the wildlife and fisheries resources and the vegetation indigenous to the area; and threatened and endangered species concerns, as well as the cultural setting issues, such as present and future land uses, are described in this section.

SECTION 3.0 WASTE CHARACTERISTICS AND SUMMARY OF EXISTING SITE DATA - describes the characteristics of the wastes present at the site, including types, volumes, and contaminant concentrations, as well as an evaluation of existing data derived from previous reclamation and response actions and investigations.

SECTION 4.0 SUMMARY OF THE APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS - presents the Montana State and Federal government requirements, which are considered applicable or relevant and appropriate (ARAR) for the reclamation effort. Requirements discussed in this section are chemical-, location-, and action-specific in nature.

SECTION 5.0 SUMMARY OF THE RISK ASSESSMENT - presents a summary of the risk assessment performed for the site.

SECTION 6.0 RECLAMATION OBJECTIVES AND GOALS - presents the reclamation objectives and applicable clean-up standards.

SECTION 7.0 DEVELOPMENT AND SCREENING OF RECLAMATION ALTERNATIVES - identifies and screens potentially applicable reclamation alternatives. Reclamation alternatives are evaluated based on effectiveness, implementability, and cost.

SECTION 8.0 DETAILED ANALYSIS OF ALTERNATIVES - presents the detailed analysis of alternatives against seven of the nine NCP criteria.

SECTION 9.0 COMPARATIVE ANALYSIS OF ALTERNATIVES - presents a comparative analysis of alternatives consistent with the NCP.

SECTION 10.0 PREFERRED ALTERNATIVE - presents the preferred alternative and summarizes the reasoning behind the selection of this alternative.

SECTION 11.0 REFERENCES - lists the references cited in the text.

2.0 BACKGROUND

The Frohner Mine Site is located in Jefferson County, Montana, in the Frohner Meadows Creek drainage basin, approximately 14 miles southwest of the town of Clancy (Figure 1-1). The tailings and waste rock piles are located within Sections 14 and 15, Township 8 North, Range 5 West of the Montana Principle Meridian (Figure 2-1). Most of the wastes at the site lie in patented claims within the Helena National Forest (85% private); however, a portion of the wastes are located on unpatented claims on USFS property (15%).

The site is accessed from Clancy, Montana, by traveling approximately 7.5 miles west on the Lump Gulch gravel road then turning northwest on the Corral Gulch gravel road (Forest Route 1878) and traveling approximately 6.5 miles to the Frohner Mine Site. The access road to the western waste rock piles (i.e. piles 1 through 6) is an unimproved dirt road with limited access due to severe erosion.

2.1 MINING HISTORY

The Frohner Mine is located within the Clancy Mining District, also known as the Clancy-Lump Gulch District. The Frohner Mine was one of the first mines in the Clancy-Lump Gulch District to be worked. It is credited with producing 161 ounces of gold (Au); 7,329 ounces of silver (Ag); 2,305 pounds of copper (Cu); 91,503 pounds of lead (Pb); and 26,000 pounds of zinc (Zn) from 1,917 tons of ore during the period of 1928 to 1954. The lower (main) adit is estimated to comprise 2,000 feet of horizontal workings that are now caved.

Although mining claims including the Frohner were located in the area at least as early as 1872, no significant development work was conducted at the Frohner Mine until about the late 1880's. Then, apparently owned and operated by the Frohner Gold and Silver Mining Company, development consisted of extending the adit and constructing a mill and boardinghouse. There are no reports of production during this period, and by 1893 the mine had closed. Later, mining activity was limited to only two episodes, one in 1911 and another in 1928-1929. Ownership during this time is unknown, although the Conrad-Stanford Company had acquired title in 1904-1905, and may have continued to hold the mine for several years. In 1939, there was a brief attempt to recover Ag from the Frohner mill tailings.

Nineteenth century production at the Frohner is unrecorded, but is presumed to have been insignificant. Documented production in the twentieth century totaled 1,917 tons. The current owner of the Frohner and Frohner Extension mining claims is apparently Barmont Mines, Inc.

The southwest corner of the Frohner site covers a portion of the Fraction Lode. Located in 1889, there is no historical evidence that the mining property was ever a producer. Sandra L. and Ronald R. Peterson are the current owners of the Fraction claim.

An adit opening and portions of four waste rock dumps are located on unpatented land surrounding the patented mining claims. The Helena National Forest administers this public land.

Waste sources at the Frohner Mine Site reside on three patented mining claims. Table 2-1 identifies each claim, the associated mineral survey number, and which waste sources are situated on the particular claim. Figure 2-2 illustrates claim boundaries and waste sources at the site.

TABLE 2-1
PROPERTY OWNERSHIP BREAKDOWN
FROHNER MINE SITE

WASTE SOURCE	CLAIM NAME	MINERAL SURVEY NO.	% PRIVATE OWNERSHIP
TP1	Frohner Extension	7,297	100%
WR1	None	None	0%
WR2	Frohner	1,321	47%
WR3	Frohner	1,321	84%
WR4	Frohner	1,321	4%
WR5	Loeber	149	88%
WR6	Loeber	149	99%
WR7	Frohner Extension	7,297	100%
SSTs	Frohner Extension	7,297	50%

Detailed information regarding the waste sources is provided in Section 3.0.

2.2 CLIMATE

The project area is subject to a cool and dry continental-dominated climate (NOAA, 1995). The region's temperature is generally cool and is marked by wide seasonal and daily variations. During the winter, the temperature often drops to zero degrees Fahrenheit (EF) with extended periods of temperatures lower than 20EF below zero. During summer, many days are fairly warm, but due to the generally arid climate and elevation (7,200 to 7,400 feet above mean sea level), temperatures decrease rapidly at nightfall. Precipitation is not abundant in the region, averaging between 18 and 20 inches annually, with most of the annual precipitation falling as snow during winter (100-200 inches average snowfall). Stormy weather usually brings the first snows during September; however, they are generally succeeded by several weeks of fair weather. By November, the area is usually covered with snow. Heavy snows are frequent in the winter, as are periods of melting and refreezing in spring. The snowpack generally remains in the area for seven months or longer, with spring thaw occurring in May or June. The area is subject to a distinct spring/summer rainy season with May and June usually being the wettest months of the year. On average, May and June each receive 2.4 inches of precipitation. The frost-free period (32ºF or more) averages 90-100 days annually, from mid-June to mid-September.

2.3 GEOLOGY, HYDROGEOLOGY, AND HYDROLOGY

2.3.1 Regional Geologic Setting

The Frohner Mine Site is located in the headwaters of Frohner Meadows Creek, which flows into Lump Gulch Creek approximately 1.5 miles downstream from the site. The region is dominated by quartz monzonite of the Boulder batholith and by alaskite with related segregations of aplite and quartz porphyry. Rhyolites are present in considerable overlying masses.

2.3.2 Local Geologic Setting

The ore vein is in quartz monzonite of the Boulder batholith. Vein material observed on the waste rock dumps consisted of considerable iron pyrite, some galena, and sphalerite in a gangue of dense white quartz.

2.3.3 Hydrogeologic Setting

There is not any published hydrogeologic information specific to this area. The information regarding hydrogeologic conditions is, therefore, based on accepted hydrologic and geologic principals and local observations. The Frohner Mine Site is located within the Frohner Meadows groundwater basin, which is part of the Lump Gulch groundwater basin.

The hydrogeologic systems contain two components: the Boulder batholith quartz monzonite and the aplite bedrock, and a thin veneer of Quaternary alluvium and/or colluvium. The bedrock is highly fractured by post-emplacement faults and joints, related to a fault zone coincident with Lump Gulch. This intense fracturing has resulted in a highly permeable and transmissive bedrock aquifer system. The alluvial deposits are small, thin, and discontinuous and are likely to transmit both surface water from local streams and discharging bedrock groundwater.

Groundwater is present in the area at a shallow depth, evidenced by the two discharging adits on the site and the Frohner Meadows wetlands area located approximately one-half mile below the Frohner Mine site. Groundwater flow likely follows local stream gradients and topography, with groundwater discharging to gaining alluvial streams, which is typical of high mountain drainage systems. Local bedrock fault systems probably exert some control on the direction and rate of groundwater flow, as do the underground workings associated with the mine workings in the area.

2.3.4 Surface Water Hydrology

The Frohner Mine Site is located at the headwaters of Lump Gulch (USGS ID MT41I00613-1998), a tributary to Prickly Pear Creek (USGS ID MT41I0061-1998 both listed on the CWA 303d 1998 Impaired Waters List for metals and suspended solids). Prickly Pear Creek flows north through the Helena Valley to the Missouri River (Upper Missouri River - USGS HUC 10030101). A drainage divide, located west of the mine, separates the Prickly Pear drainage from the Tenmile Creek drainage. The drainage that flows into the Frohner Basin is a first order stream. The second order stream is Lump Gulch Creek. Lump Gulch and Prickly Pear Creeks are classified as B-1 streams by the Montana Water Quality Bureau (ARM 16.20.618). Limited streamflow information for the Frohner Basin indicates that flows in the fall and summer are less than 0.022 cubic feet per second (cfs) (100 gallons per minute [gpm]) and have been estimated as high as 4 cfs (1,800 gpm) during spring runoff.

Discharge from Adit 2 seeps into waste rock dump #7 (WR7) and re-emerges at the base of WR7, where it flows into Frohner Meadows Creek. The Adit 2 discharge was measured during the Final Adit Baseline Characterization Investigation (DEQ/MWCB-Pioneer, 1998b) at flows ranging from 0.001 to 0.03 cfs (0.5 to 15 gpm).

The Frohner Meadows Creek drainage basin occupies an area of approximately 2.2 square miles of generally steep forested terrain and originates north of the mine site. The drainage area contributing to the Frohner Mine Site occupies an area of approximately 0.4 square mile of steep forested terrain. The creek occurs in a narrow valley floor of usually less than 35 feet in width. Elevation differences from the valley floor to adjacent ridgelines are on the order of 800 feet. The creek stream channel is generally less than 10 feet wide. Stream flow estimates made during the site characterization averaged approximately 0.140 cfs (63 gpm). The stream channel has a steep gradient for most of its length (average 9 percent).

The Frohner Meadows Creek drainage does not contain a gauging station. The U.S. Geological Survey (USGS) report, "Revised Techniques for Estimating Magnitude and Frequency of Floods in Montana" (USGS Open-File Report 92-4048) was used to estimate the peak flood events in Frohner Meadows Creek. The following is a summary of the peak flood flow estimates for various recurrence intervals:

Q_2 = 2.7 cfs;
Q_{10} = 8.9 cfs;
Q_{25} = 15.3 cfs;
Q_{50} = 19.9 cfs;
Q_{100} = 25.2 cfs; and
Q_{500} = 39.5 cfs

The designation "Q_n" above represents the magnitude of the estimated peak flow rate observed in Frohner Meadows Creek for a flooding event with a "n"-year frequency return period.

Tailings pile (TP1) is located within the Frohner Meadows Creek floodplain. The impoundment occupies the valley floor in which it was deposited and has a maximum depth of five feet. Frohner Meadows Creek is immediately adjacent to TP1 and has incised into the tailings to a depth of approximately six inches to one foot.

Due to the steep terrain at the site, the toe or lower portions of WR7 is located in the Frohner Meadows Creek and/or its floodplain. Most of the waste rock pile contains relatively unaltered andesitic wall rock with minor mineralized quartz vein material. Iron oxide alteration of primary sulfides in the vein material appears to be more prevalent on the surface of the waste rock piles. During the site characterization, which corresponded to base flow conditions, Frohner Meadows

Creek was not observed to be in contact with the other waste rock piles. The exception is the drainage route on WR7 from the flowing adit (Adit 2), which appears to discharge perennially.

2.4 CURRENT SITE SETTING

2.4.1 Location and Topography

The Frohner Mine Site is located in the Lump Gulch portion of the Clancy-Lump Gulch Mining District in Jefferson County, Montana (Chessman Reservoir USGS 7.5 Minute Quadrangle). The site consists of 12 patented mining claims, on privately owned land, within and bordered by lands administered by the Helena National Forest, Helena Ranger District. Elevation at the Frohner Mine Site is 7,200 feet above mean sea level and greater (DEQ/MWCB-Pioneer, 1995). The legal description of the Frohner Mine Site is Township 8 North, Range 5 West, SE ¼ of the NW ¼ of the SE ¼ of Section 15 and the SW ¼ of Section 14 of the Montana Principle Meridian.

The Frohner Mine Site is located upgradient (southwest) of the Nellie Grant and the General Grant Mines. The headwaters of Frohner Meadows Creek flow through the lower portion of the site. The Frohner Meadows Creek enters Frohner Meadows approximately 1.5 miles below the Frohner Mine Site. A discharging adit (Adit 1) is located at the upper portion of the site and typically has low flows (generally below 1 gpm) throughout most of the year except during spring runoff, where a flow of 0.03 cfs (14.5 gpm) was measured during the May through June, 1996, sampling round of the Final Adit Baseline Characterization Investigation (DEQ/MWCB-Pioneer, 1998b).

Mining-related features associated with the Frohner Mine Site include seven waste rock dumps, five collapsed adits (two discharging), three shafts (two capped and one fenced), one fenced stope, and one tailings pile. There are two collapsing wooden cabins near the upper portion of the site, and an ore loadout and collapsed rock and mortar mill structure at the lower portion of the site.

The mining wastes associated with the site, the discharging adits, and the SSTs are all located in the headwaters of Lump Gulch Creek, on relatively steep terrain. The largest waste rock dump (WR7) contains approximately 4,500 cubic yards (cy) of material located directly in the floodplain of Frohner Meadows Creek and it is actively eroding into the stream. In addition, the discharge from Adit 2 flows directly through WR7 and into a small pond where it seeps through the dump and emerges at the base of WR7 before entering Frohner Meadows Creek. No vegetation is found on WR7; the waste rock dump material has a measured pH below 3.5. The other six waste rock dumps are located in the upper portion of the site away from any active drainages and contain much smaller volumes of waste rock with the exception of WR6, which has a volume of approximately 850 cy and is proximal to an ephemeral surface water conveyance. The mill tailings pile (TP1) contains approximately 538 cy and is located directly in the floodplain of Frohner Meadows Creek. No vegetation is found on the mill tailings and they are actively eroding into the stream.

2.4.2 Vegetation/Wildlife

The entire Frohner Mine Site is located in a timbered subalpine easterly facing slope with limited amounts of open grassland. The current dominant vegetation is Lodgepole pine, grasses, and some aspen trees. There were no known sensitive, threatened, or endangered plant species observed in the study area. There were no noxious weeds found at the site. Riparian communities occur in the study area associated with Frohner Meadows Creek. In general, the area is fairly continually forested and is important habitat for a variety of big game animals, fur bearers, and birds including: mule deer, elk, bear, mountain lion, bobcat, and mountain grouse.

2.4.3 Historic or Archaeologically Significant Features

In June 1998, Mr. Dale Gray and Mr. Bill Fischer completed a field inventory for the DEQ/MWCB in order to identify and evaluate cultural resources at the Frohner Mine and Mill (24JF1560) and the Clancy Historic Mining District (24JF1393).

The inventory was conducted to satisfy federal and state legislation requiring cultural resources inventories in compliance with the National Historic Preservation Act (Public Law 89-665, as amended), the National Environmental Policy Act, and the Montana Environmental Policy Act, as well as other state and federal requirements. The purpose of a cultural resources inventory is to locate, record, and evaluate the kinds and nature of the resources within the vicinity of the project area and to evaluate those resources in terms of the National Register of Historic Places (NHRP).

The study examined the site to determine: 1) if any cultural resources were within the project area; and 2) the value of the identified resources in terms of the NRHP. One historic site was recorded: the Frohner Mine and Mill (24JF1560). The site is recommended individually to be eligible for the NRHP. The features are documented to have poor integrity, but the site as a whole qualifies for the NRHP as a site, historic landscape, and a sub-district and as a contributing component of the Clancy Historic Mining District Sub-areas (24JF1541). Avoidance of the remaining features at the Frohner Mine and Mill is recommended.

2.4.4 Land Use and Population

Existing use of this land is recreational and wildlife habitat. There are no permanent residents located within one mile of the site. However, the town of Rimini is located approximately four miles northwest of the site in the Tenmile Creek drainage basin, which is separated from the Prickly Pear drainage basin by a topographic divide. An estimated 30 residents live year-round in the town of Rimini, while several part-time or recreational residents inhabit the general area.

3.0 FROHNER MINE SITE

Results of reclamation investigation activities completed at the Frohner Mine Site are presented in this section.

3.1 PREVIOUS FIELD INVESTIGATION

During 1995 and 1996, two studies that collected waste source data were completed at the Frohner Mine Site. These studies included the Abandoned Mine Site Inventory (DEQ/MWCB-Pioneer, 1995) and the Final Adit Baseline Characterization Investigation (DEQ/MWCB-Pioneer, 1998b).

In June 1998, a Reclamation Work Plan was prepared for the Frohner Mine Site (DEQ/MWCB-Pioneer, 1998a). The Reclamation Work Plan was prepared to be a functional guide for conducting the full-scale reclamation at the Frohner Mine Site and outlines site characterization tasks necessary to support both the risk assessment and feasibility study. The data identified to complete the risk assessment and the feasibility study include the following:

Risk Assessment Data Requirements

- establish background soil concentrations with background samples;
- characterize vertical and lateral metal concentration variations in waste sources;
- evaluate the physical and chemical properties of the source material that may affect contaminant migration including: pH, buffering capacity, organic carbon content, and particle size distribution;
- characterize impacts to surface water with strategically located surface water samples in the Frohner Meadows Creek;
- characterize potential impacts to shallow groundwater by conducting limited groundwater modeling; and
- assess surface water uses and estimate other ecological uses.

Feasibility Study Data Requirements

- determine accurate areas and volumes of the contaminant source materials including tailings, waste rock piles, and stockpiles of mine ore and mill concentrates;
- contaminant concentration variations and leaching characteristics of the waste (Toxicity Characteristic Leaching Procedure [TCLP], porosity, and hydraulic conductivity);

- representative acid/base accounting characteristics of the tailings, waste rock, mine ore, and mill concentrates;

- depth and gradient of shallow groundwater;

- hydrologic configuration of Frohner Meadows Creek;

- potential location for repository site; and

- identification of potential borrow source areas for cover soil, clay, riprap, and/or limestone.

A Field Sampling Plan (FSP) and Quality Assurance Project Plan (QAPjP) were also developed as part of the Reclamation Work Plan. These documents outlined the sampling and analytical methods used to generate sufficient site characterization data to complete a risk assessment and a detailed analysis of reclamation alternatives. Pioneer performed the site characterization work outlined in the FSP during November 1999.

The principal techniques used for data acquisition in this site investigation were backhoe test pits and field mapping, and soil, sediment, and water sampling. Samples were collected using standard operating procedures that are contained in the FSP (DEQ/MWCB-Pioneer, 1999a). Analytical data were evaluated for quality assurance according to the QAPjP (DEQ/MWCB-Pioneer, 1999b).

The site characterization field program included collecting solid samples for the following types of analyses:

- Target analyte list (TAL) analyses include total metals and non-metals following the Contract Laboratory Program (CLP) Methods for determining the concentrations of the following elements: Ag, As, Cd, copper (Cu), Fe, Hg, manganese (Mn), Pb, Sb, Tl, and Zn. Laboratory analyses for the TAL were all performed by the MSE-HKM Laboratory located in Butte, Montana.

- Acid/Base Accounting (ABA) analyses including determination of sulfur fractions, neutralization potential, SMP buffer, and exchangeable acidity. These analyses were all performed by MSE-HKM.

- Hazardous waste characteristics, determined by analysis for TCLP metals analysis. These analyses were performed by MSE-HKM.

- Agronomics analyses included determination of percent organic matter, fertilizer required, field capacity, wilting point, and percent available moisture.

- Samples for physical characteristics (atterberg limits, proctor, gradation, etc.) were collected, but not analyzed pending necessity.

The site characterization evaluated eight potential waste sources. These sources included one tailings pile and seven waste rock piles. General information regarding samples collected from each waste source is provided in Table 3-1. Surface water and sediment samples are summarized in Table 3-2. Adit discharge samples are summarized in Table 3-3. General site features, locations of the wastes sources and sample locations at the site are shown on Figure 3-1. The following subsections summarize the results of the site characterization data for each of the waste sources.

3.2 MINE WASTE SOURCES

This section discusses each mine waste source present at the Frohner site. Figures 3-1 and 3-2 show the location of each source, illustrate the major site features (topography, roads, waste sources, surface water, drainage patterns, etc.), and indicate the location of each sample collected at the site during the field activities. Appendix A contains laboratory analytical results for background soil, waste, sediment, and water samples.

3.2.1 Waste Rock Dump #1

Waste rock dump #1 (WR1) is located on the northwestern part of the site, on the middle of a moderately sloping hillside and distant from surface water conveyances (Figure 3-1). There is a collapsed shaft and the remains of a hoist building on the north end of the dump. WR1 is not easily accessible by vehicles and is located entirely on lands administered by the Helena National Forest (Table 2-1). The volume of WR1 is approximately 500 cy and has a surface area of 0.13 acre.

One test pit was excavated into the west side of WR1 using a backhoe. The total depth of the pit was 11 feet, but did not reach natural soils at the bottom. The dump contained abundant pyrite and galena, was tan to yellow in color, with approximately 15% rock greater than 3 inches in diameter.

One composite sample was collected from WR1 for metals, ABA, and agronomic analyses (22-243-WR1). Tables A-1, A-2, A-3, and A-4 (Appendix A) show the analytical results for WR1. General waste source sample data are provided in Table 3-4.

Concentrations of the following metals were determined to be significantly elevated above background (>3X) in the WR1 dump: As, Pb, Hg, and Ag. ABA data were obtained for WR1 for the reclamation scenarios involving stabilizing and revegetating WR1 in place. The ABA and SMP buffering capacity results indicate that WR1 is considered a potential acid producer and approximately 122.6 tons of lime per acre would be required to successfully buffer this material to establish vegetation assuming a 12-inch depth of incorporation. The pH ranged from 2.2 to 3.0 in the WR1 sample; many state regulatory programs consider pH levels less than 5.5 as unsuitable for plant growth.

According to the TCLP data obtained for WR1, the concentration of Pb measured in laboratory generated leachate (17.9 mg/L) is above the regulatory limits for hazardous waste classification. Consequently, WR1 satisfies the criteria to be considered a Resource Conservation and Recovery Act (RCRA) characteristic hazardous waste (EPA hazardous waste number D008); however, the Bevill Amendment may exclude this waste from RCRA regulations because the waste was derived from the extraction, beneficiation, and/or processing of ores or minerals.

Fertilizer recommendation analyses provided the following results for WR1: 40 pounds nitrogen (as N); 20 pounds of phosphate (P_2O_5); and 30 pounds of potash (K_2O) required per acre. Organic amendment of the dump material is advised due to the very low organic matter content (1.1%). In addition to providing temporary stabilization of the disturbed erodible surfaces, application of wheat or barley straw mulch would assist in providing necessary organic material to help promote successful revegetation. The breakdown of the revegetation requirements, as presented, should be considered preliminary at this time (for planning purposes only). WR1 will be re-sampled, and the results will be re-evaluated when and if the dump has been recontoured, amended, and prepared for revegetation.

3.2.2 Waste Rock Dump #2

Waste rock dump #2 (WR2) is located on the northwestern part of the site, south of WR1, on the middle of a moderate hillside and distant from surface water conveyances (Figure 3-1). There is a covered shaft on the north end of the dump. WR2 is not easily accessible by vehicles and is located on both private mining claims (47%) and lands administered by the Helena National Forest (53%) (Table 2-1). The volume of WR2 is approximately 260 cy and has a surface area of 0.10 acre (Table 3-4).

One test pit was excavated into the center of WR2 using a backhoe. The total depth of the pit was 7 feet, and reached natural soils at 5.5 feet. The dump contained abundant pyrite and galena, was light yellow in color, with approximately 5% rock.

One composite sample was collected from WR2 for metals, ABA, and agronomic analyses (22-243-WR2-1). Tables A-1, A-2, A-3, and A-4 (Appendix A) show the analytical results for WR2. Table A-1 (Appendix A) presents the metals data obtained for WR2. Concentrations of the following metals were significantly elevated above background (>3X) in the dump: As, Cu, Pb, Ag, and Zn. ABA data were obtained for WR2 for the reclamation scenarios involving stabilizing and revegetating WR2 in place. The ABA and SMP buffering capacity results indicate that WR2 is considered a potential acid producer and approximately 56.1 tons of lime per acre would be required to successfully establish vegetation on this material, assuming a 12-inch depth of incorporation. The pH was 2.2 in the sample from WR2; many state regulatory programs consider pH levels less than 5.5 as unsuitable for plant growth.

According to the TCLP data obtained for WR2, the concentrations measured in laboratory generated leachate were not above the regulatory limits for hazardous waste classification. Consequently, WR2 does not satisfy the criteria to be considered a RCRA characteristic hazardous waste.

Fertilizer recommendation analyses provided the following results for WR2: 50 pounds nitrogen (as N); 15 pounds of phosphate (P_2O_5); and 30 pounds of potash (K_2O) required per acre. Organic amendment of the dump material is advised due to the very low organic matter content (0.1%). In addition to providing temporary stabilization of the disturbed erodible surfaces, application of wheat or barley straw mulch would assist in providing necessary organic material to help promote successful revegetation. The breakdown of the revegetation requirements, as presented, should be considered preliminary at this time (for planning purposes only). WR2 will be re-sampled, and the results will be re-evaluated when and if the dump has been recontoured, amended, and prepared for revegetation.

3.2.3 Waste Rock Dump #3

Waste rock dump #3 (WR3) is located in the central part of the site, southeast of WR1 and WR2, near the base of a moderate hillside, but still distant from surface water conveyances (Figure 3-1). There is a covered shaft on the north end of the dump. WR3 is easily accessible by vehicles and is located on both private mining claims (84%) and lands administered by the Helena National Forest (16%) (Table 2-1). The volume of WR3 is approximately 1,160 cy and the dump has a surface area of 0.46 acre (Table 3-4).

Two test pits were excavated into WR3 using a backhoe. The total depth of both pits was seven feet and reached natural soils at the bottom. The dump contained abundant pyrite, sphalerite, and galena, was light tan to light yellow in color, with approximately 45% rock.

One composite sample was collected from WR3 for metals, ABA, and agronomic analyses (22-243-WR3-1). Tables A-1, A-2, A-3, and A-4 (Appendix A) show the analytical results for WR3. Table A-1 (Appendix A) presents the metals data obtained for WR3. Concentrations of the following metals were significantly elevated above background (>3X) in the dump: Sb, As, Cd, Cu, Fe, Pb, Hg, Ag, and Zn. ABA data were obtained for WR3 for the reclamation scenarios involving stabilizing and revegetating WR3 in place. The ABA and SMP buffering capacity results indicate that WR3 is considered a potential acid producer and approximately 69.5 tons of lime per acre would be required to successfully establish vegetation on this material, assuming a 12-inch depth of incorporation. The pH ranged from 2.51 to 3.0 in the WR3 sample; many state regulatory programs consider pH levels less than 5.5 as unsuitable for plant growth.

According to the TCLP data obtained for WR3, the concentration of Pb measured in laboratory generated leachate (67.6 mg/L) is above the regulatory limits for hazardous waste classification. Consequently, WR3 satisfies the criteria to be considered a RCRA characteristic hazardous waste (EPA hazardous waste number D008); however, the Bevill Amendment may exclude this waste from RCRA regulations because the waste was derived from the extraction, beneficiation, and/or processing of ores or minerals.

Fertilizer recommendation analyses provided the following results for WR3: 45 pounds nitrogen (as N); 15 pounds of phosphate (P_2O_5); and 35 pounds of potash (K_2O) required per acre. Organic amendment of the dump material is advised due to the very low organic matter content (0.3%). In addition to providing temporary stabilization of the disturbed erodible surfaces, application of wheat or barley straw mulch would assist in providing necessary organic material to help promote successful revegetation. The breakdown of the revegetation requirements, as presented, should be considered preliminary at this time (for planning purposes only). WR3 will be re-sampled, and the results will be re-evaluated when and if the dump has been recontoured, amended, and prepared for revegetation.

3.2.4 Waste Rock Dump #4

Waste rock dump #4 (WR4) is located immediately west of WR3 (Figure 3-1). WR4 is not completely accessible by vehicles. The volume of WR4 is approximately 450 cy and the dump has a surface area of 0.11 acre (Table 3-4). It does not have vegetation on its surface although it does have vegetation and timber surrounding its footprint. WR4 is located on both private mining claims (4%) and lands administered by the Helena National Forest (96%) (Table 2-1).

Test pits were not excavated into WR4 and no samples were collected from WR4. Table 3-5 presents the XRF metals data obtained for WR4 during the 1995 inventory. Concentrations of the following metals were significantly elevated above background (>3X) in the dump: As, Pb, Ag, and Zn. Since concentrations of Pb are 5% of concentrations occurring in WR3, TCLP results for Pb should be approximately 5% of WR3 or 3.4 mg/L and below regulatory limits.

TABLE 3-5
XRF CONCENTRATIONS FOR WR4 (Pioneer, 1995)

PARAMETER	CONCENTRATION (ppm)	PARAMETER	CONCENTRATION (ppm)
K	34,862	Sr	51.197
Ca	1,551.5	Zr	157.21
Tl	1,143.9	Mo	N.R.
Mn	365.14*	Pb	1,538.9
Fe	14,092	Rb	231.3
Zn	169.84	Ba	449.96
As	637.94	Ag	89.055*
Se	N.R.		

N.R. - Not Reported.
* - More than 3x detection limit and less than 10x the detection limit.

3.2.5 Waste Rock Dump #5

Waste rock dump #5 (WR5) is located at the extreme western side of the site, west of WR3 on the side of a very steep hillside, distant from surface water conveyances (Figure 3-1). WR5 is accessible by vehicles and is located on both private mining claims (88%) and lands administered by the Helena National Forest (12%) (Table 2-1).

No test pits were excavated in this dump and no samples were collected. Because of its close proximity and similarity to WR6, data from WR6 adequately characterize WR5. The volume of WR5 is approximately 1,180 cy and the dump has a surface area of 0.26 acre (Table 3-4).

3.2.6 Waste Rock Dump #6

Waste rock dump #6 (WR6) is located in the western part of the site, southwest of WR3 and east of WR5, at the base of a steep hillside, proximal to an ephemeral surface water conveyance (Figure 3-1). There is a collapsed adit on the west end of the dump and a minor adit seepage. WR6 has limited accessibility by vehicles and is located on both private mining claims (99%) and lands administered by the Helena National Forest (1%) (Table 2-1). The volume of WR6 is approximately 850 cy and the dump has a surface area of 0.23 acre (Table 3-4).

One test pit was excavated into WR6 using a backhoe. The total depth of the pit was five feet and reached natural soils at the bottom. The dump was sparsely vegetated, was light to medium brown in color, with approximately 25% rock.

One composite sample was collected from WR6 for metals, ABA, and agronomic analyses (22-243-WR6). Tables A-1, A-2, A-3, and A-4 (Appendix A) show the analytical results for WR6. Table A-1 (Appendix A) presents the metals data obtained for WR6. Concentrations of the following metals were significantly elevated above background (>3X) in the dump: As, Cu, Pb, Hg, Ag, and Zn. ABA data were obtained for WR6 for the reclamation scenarios involving stabilizing and revegetating WR6 in place. The ABA and SMP buffering capacity results indicate that WR6 is considered a potential acid producer and approximately 26.7 tons of lime per acre would be required to successfully establish vegetation on this material, assuming a 12-inch depth of incorporation. The pH ranged from 2.97 to 3.6 in the WR6 sample; many state regulatory programs consider pH levels less than 5.5 as unsuitable for plant growth.

According to the TCLP data obtained for WR6, the concentrations measured in laboratory generated leachate were not above the regulatory limits for hazardous waste classification. Consequently, WR6 does not satisfy the criteria to be considered a RCRA characteristic hazardous waste.

Fertilizer recommendation analyses provided the following results for WR6: 45 pounds nitrogen (as N); 15 pounds of phosphate (P_2O_5); and 30 pounds of potash (K_2O) required per acre. Organic amendment of the dump material is advised due to the very low organic matter content (0.4%). In addition to providing temporary stabilization of the disturbed erodible surfaces, application of wheat or barley straw mulch would assist in providing necessary organic material to help promote successful revegetation. The breakdown of the revegetation requirements, as presented, should be considered preliminary at this time (for planning purposes only). WR6 will be re-sampled, and the results will be re-evaluated when and if the dump has been recontoured, amended, and prepared for revegetation.

3.2.7 Waste Rock Dump #7

WR7 is located in the central part of the site, east of WR3, west of TP1, at the base of a moderate sloping hillside, and adjacent to perennial surface water - Frohner Meadows Creek (Figure 3-2). WR7 is easily accessible by vehicles and is located entirely on private mining claims. The volume of WR7 is approximately 4,500 cy and the dump has a surface area of 0.71 acre (Table 3-4).

Two test pits were excavated into WR7 using a backhoe. Pit 7-1 was located on the central-west portion of the dump and had a total depth of 7.5 feet, encountered groundwater at 5 feet, and did not reach natural soils. The pit material was light grey to rust stained in color, with approximately 45% rock. Pit 7-2 was located on the northern portion of the dump and had a total depth of 11 feet and reached natural soils at the bottom. The pit material was light grey to light green in color, with minimal rock.

Two composite samples were collected from WR7 for metals, ABA, and agronomic analyses (22-243-WR7-1 and WR7-2). Tables A-1, A-2, A-3, and A-4 (Appendix A) show the analytical results for WR7. Table A-1 (Appendix A) presents the metals data obtained for WR7. Concentrations of the following metals were significantly elevated above background (>3X) in the dump: As, Pb, and Ag. ABA data were obtained for WR7 for the reclamation scenarios involving stabilizing and revegetating WR7 in place. The ABA and SMP buffering capacity results indicate that WR7 is considered a potential acid producer and approximately 68.1 tons of lime per acre would be required to successfully establish vegetation on this material, assuming a 12-inch depth of incorporation. The pH was 2.2 in the sample from WR7; many state regulatory programs consider pH levels less than 5.5 as unsuitable for plant growth.

According to the TCLP data obtained for WR7, the concentration of Pb measured in laboratory generated leachate (29.9 and 12.2 mg/L) is above the regulatory limits for hazardous waste classification. Consequently, WR7 satisfies the criteria to be considered a RCRA characteristic hazardous waste (EPA hazardous waste number D008); however, the Bevill Amendment may exclude this waste from RCRA regulations because the waste was derived from the extraction, beneficiation, and/or processing of ores or minerals.

Fertilizer recommendation analyses provided the following results for WR7: 45 pounds nitrogen (as N) required per acre; 25 pounds of phosphate (P_2O_5); and 30 pounds of potash (K_2O) required per acre. Organic amendment of the dump material is advised due to the very low organic matter content (0.8%). In addition to providing temporary stabilization of the disturbed erodible surfaces, application of wheat or barley straw mulch would assist in providing necessary organic material to help promote successful revegetation. The breakdown of the revegetation requirements, as presented, should be considered preliminary at this time (for planning purposes only). WR7 will be re-sampled, and the results will be re-evaluated when and if the dump has been recontoured, amended, and prepared for revegetation.

3.2.8 Tailings Pile #1

TP1 is located on the eastern edge, east of WR7, and adjacent to perennial surface water - Frohner Meadows Creek (Figure 3-2). TP1 is easily accessible by vehicles and is located entirely on private mining claims. The volume of TP1 is approximately 500 cy and has a surface area of 0.61 acre (Table 3-4).

Two test pits were excavated into TP1 using a backhoe. Pit 1A was located in the south-central portion of the tailings and had a total depth of 4.5 feet to natural soils. The pit material was light grey to yellow in color, grading from coarse sand to clays. Pit 1B was located on the southwest portion of the tailings and had a total depth of 1.8 feet to natural soils. The pit material was similar to 1A.

One composite sample was collected from TP1 for metals and ABA analyses (22-243-TP1). Tables A-1, A-2, A-3, and A-4 (Appendix A) show the analytical results for TP1. Table A-1 (Appendix A) presents the metals data obtained for TP1. Concentrations of the following metals were significantly elevated above background (>3X) in the dump: Sb, As, Cd, Cu, Pb, Hg, Ag, and Zn. ABA data were obtained for TP1 for the reclamation scenarios involving stabilizing and revegetating TP1 in place. The ABA and SMP buffering capacity results indicate that TP1 is considered a potential acid producer and approximately 57.1 tons of lime per acre would be required to successfully establish vegetation on this material, assuming a 12-inch depth of incorporation. The pH ranged from 2.5 to 2.68 in the TP1 sample; many state regulatory programs consider pH levels less than 5.5 as unsuitable for plant growth.

According to the TCLP data obtained for TP1, the concentration of Pb measured in laboratory generated leachate (143 mg/L) is above the regulatory limits for hazardous waste classification. Consequently, TP1 satisfies the criteria to be considered a RCRA characteristic hazardous waste (EPA hazardous waste number D008); however, the Bevill Amendment may exclude this waste from RCRA regulations because the waste was derived from the extraction, beneficiation, and/or processing of ores or minerals.

Fertilizer recommendation analyses provided the following results for TP1: 45 pounds nitrogen (as N); 20 pounds of phosphate (P_2O_5); and 35 pounds of potash (K_2O) required per acre. Organic amendment of the dump material is advised due to the very low organic matter content (0.8%). In addition to providing temporary stabilization of the disturbed erodible surfaces, application of wheat or barley straw mulch would assist in providing necessary organic material to help promote successful revegetation. The breakdown of the revegetation requirements, as presented, should be considered preliminary at this time (for planning purposes only). TP1 will be re-sampled, and the results will be re-evaluated when and if the dump has been recontoured, amended, and prepared for revegetation.

During the field investigation, numerous streamside tailing deposits were recorded below TP1 along Frohner Meadows Creek (Figure 3-2). These deposits were not surveyed or sampled during this investigation.

3.2.9 Adit Discharges

There are two discharging adits at the Frohner Mine Site, which were sampled during the 1995-1996 Adit Baseline Characterization Investigation. Adit 1 is located at WR6 (Figure 3-1) and was sampled during the third and fourth rounds, as it was dry during the second round. Adit 2 (Figure 3-2) is located at WR7 and was sampled during the second, third, and fourth rounds. These adits were not sampled during the 1999 investigation because sufficient data had been collected during the previous Adit Baseline Characterization Investigation. Refer to Tables A-7 (total metals data), A-8 (dissolved metals data), and A-9 (field parameters and wet chemistry) in Appendix A for analytical and field data.

Adit 1 - Results from the third and fourth rounds of sampling indicate the majority of Cd, Pb, manganese, and Zn were in the dissolved phase and a slight increase in metals concentrations were present during the fourth round for As, Fe, Pb, manganese, and Zn. Both Fe and As speciation were performed on this adit discharge. Fe was entirely in the reduced state (Fe^{+2}) while As concentrations were too low for speciation analysis. Flow increased substantially during the third sampling round in the spring from less than 1 gpm during the other rounds to 14.5 gpm. The pH was relatively unchanged compared to the other rounds while TDS, Sulfate, Hardness, and SC showed a noticeable decrease. Water quality exceedances for Human Health Standards (HHSs), Acute Aquatic Life Standards (AALS), Chronic Aquatic Life Standards (CALS), and Maximum Contaminant Levels (MCLs) were reported for this adit. Cd, Cu, manganese, Pb, Sb, and Zn were in exceedance during both rounds of sampling. Fe and Tl were in exceedance only during the fourth round. Analytical results are presented in Tables A-6 and A-7 in Appendix A.

Adit 2 - Results from the second, third and fourth rounds of sampling indicated the majority of aluminum, As, Cd, Fe, Pb, manganese, and Zn exist in the dissolved phase. A slight increase in aluminum and Zn concentrations and a slight decrease in As, Fe, and manganese concentrations occurred during the third round. Fe and manganese showed small increases to their highest level during the fourth round of sampling. Both Fe and As speciation were performed during the second, third, and fourth rounds. The Fe speciation results varied from round to round, with Fe^{+2} the predominant oxidation state in the second round, Fe^{+2} and Fe^{+3} were nearly equivalent during the third round, and Fe^{+3} was slightly higher during the fourth round. As was predominantly in the oxidized state (As^{+5}) during all three rounds. Flow rates varied widely, with the highest flow of approximately 15 gpm during the third round and lowest flow of 0.5 gpm during the second round. The pH remained fairly constant throughout, while the TDS concentration was lowest and EH highest during the third sampling round. Water quality exceedances for HHSs, AALS, CALS, and MCLs were reported at this adit. As, Cd, Cu, Fe, manganese, Pb, and Zn were in exceedance during all three sampling rounds. Thallium was only in exceedance during the third and fourth rounds, and Sb was only in exceedance during the fourth round. Analytical results are presented in Tables A-6 and A-7 in Appendix A.

3.3 SURFACE WATER

A total of four paired surface water and sediment samples were collected from the Frohner Mine Site during the reclamation investigation (Table 3-2). Each surface water sample was analyzed for total recoverable metals (TRM) and wet chemistry parameters (sulfate, hardness, and TDS). Analytical results are included in Tables A-5, A-6, and A-10 in Appendix A. Each sediment sample was submitted to the laboratory for TAL metals analysis. One of the sample locations (SW1/SE1) was upgradient of mine waste sources. Surface water samples collected downgradient of the mine waste sources (including waste rock and tailings dumps, and Adit 2 discharge) were generally of poor quality. Exceedances of water quality standards at each station are summarized in Table 3-6.

TABLE 3-6
SURFACE WATER QUALITY STANDARD EXCEEDANCES
FROHNER MEADOWS CREEK

SAMPLE LOCATION	WATER QUALITY STANDARD EXCEEDANCES						
	Cd	**Cu**	**Fe**	**Mn**	**Pb**	**Zn**	**As**
25-287-SW-01 Upgradient	None	None	None	None	None	None	None
25-287-SW-02 Below WR7 and Adit 2 discharge	CAL, AAL, HHS, MCL	CAL	CAL, HHS	HHS	CAL, HHS	CAL, AAL	HHS
25-287-SW-03 Below TP1	CAL, AAL	CAL	HHS	HHS	CAL, AAL	CAL, AAL	HHS
25-287-SW-04 Downgradient	CAL, AAL	None	HHS	HHS	HHS	CAL, AAL	HHS

CAL = Chronic aquatic life standard (WQB-7).
AAL = Acute aquatic life standard (WQB-7).
HHS = Montana Human Health Standard (WQB-7).
MCL = Safe Drinking Water Act Maximum Contaminant Level.

A concentration analysis was performed to attempt identification of the contributions to surface water and sediment from the several contaminant sources present at the site. Significant increases of contaminants between two sample stations are indicative of contributions originating at a source located between the two stations. The analysis results are presented in Table 3-7 and allows a comparison between the sources for each contaminant.

Elevated metal concentrations in surface water appear not to be related to a specific source, but are related to site-wide contaminants. Metal concentrations in stream sediments may be source-related, with Hg, Ag, and Pb significantly elevated below TP1.

TABLE 3-7
SIGNIFICANT SURFACE WATER AND SEDIMENT CONCENTRATION INCREASES
FROHNER MEADOWS CREEK

STREAM REACH	SOURCES WITHIN REACH	ELEVATED TOTAL METALS IN SURFACE WATER	ELEVATED TOTAL METALS IN STREAM SEDIMENT
SW-1 to SW-2	WR7, AD2	As, Cd, Cu, Fe, Pb, Mn, Zn, Sulfate, -Ag	+As, Cd, Cu, Fe, Pb, Mn, Hg, Ag, Zn
SW-2 to SW-3	TP1	As, Cd, Cu, Fe, Pb, Mn, Zn, Sulfate, +Ag	Cd, Fe, Mn, Zn, +As, Cu, Pb, Hg, Ag
SW-3 to SW-4	None	As, Cd, Cu, Fe, Pb, Mn, Ag, Zn, Sulfate	Hg, Ag, +As, Cd, Cu, Fe, Pb, Mn, Zn

+ means that concentration significantly increased from previous station.

- means that concentration decreased from previous station.

4.0 SUMMARY OF THE APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

The summary of the ARARs was compiled from a draft document describing ARARs for abandoned mine sites produced by the DEQ/MWCB. These ARARs were reviewed to develop a listing of potential federal and state ARARs for the Frohner Mine site. The federal and state ARARs are summarized in Tables 4-1 and 4-2, respectively. Appendix B provides detailed descriptions of potential federal and state ARARs. The description of the federal and state ARARs includes summaries of legal requirements that, in many cases, attempt to set out the requirement in a simple fashion useful in evaluating compliance with the requirement. In the event of any inconsistency between the law itself and the summaries in this section, the ARAR is ultimately the requirement as set out in the law, rather than any paraphrase provided here.

5.0 HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS

Human health and environmental threats associated with exposure to mine waste at the Frohner Mine Site have been evaluated through a risk assessment process. The risks were evaluated using site specific chemical concentrations and applicable exposure pathways. This assessment follows risk assessment procedures for abandoned mine sites as developed by the DEQ/MWCB.

5.1 BASELINE HUMAN HEALTH RISK ASSESSMENT

The baseline human health risk assessment performed for the Frohner Mine Site generally follows the Federal Remedial Investigation/Feasibility Study (RI/FS) process for CERCLA (Superfund) sites (EPA, 1988a). The baseline human health risk assessment examines the effects of taking no further remedial action at the site. This abbreviated assessment involves two steps: hazard identification and risk characterization. These tasks are accomplished by evaluating available data and selecting contaminants of concern (CoCs), comparing those concentrations to previously derived cleanup goals, and characterizing overall risk by integrating the results of the comparison. These previously derived cleanup goals include recreational cleanup goals for abandoned mine sites, completed for the DEQ/MWCB (TetraTech, 1996), and the EPA Region III risk-based concentration table (Smith, 1995) for residential cleanup goals.

General problems at the Frohner Mine Site that could impact human health include elevated concentrations of metals and As in waste materials, surface water and stream sediments. The easily accessible waste materials may result in significant health-related consequences to the human population.

5.1.1 Hazard Identification

The initial task of the risk assessment is to select the CoCs at the site to identify those that pose significant potential human health risks. Standard EPA criteria for this selection include: 1) those contaminants that are associated with and are present at the site; 2) contaminants with average concentrations at least three times above background levels; 3) contaminants with at least 20% of the measured concentrations above the detection limit; and 4) contaminants with acceptable quality assurance/quality control (QA/QC) results applied to the data.

At the Frohner Mine Site, waste rock, mill tailings, surface water, and stream sediments were analyzed for a list of 11 elements. Eight of these constituents meet the above criteria for classification as CoCs for the Frohner Mine Site: Sb, As, Cd, Cu, Pb, Hg, Ag, and Zn. These were selected for detailed evaluation because they are present in significant concentrations in wastes, stream sediments, and surface water at the site.

5.1.2 Exposure Scenarios

The exposure assessment identifies the potentially exposed population(s) and exposure pathways and estimates exposure point concentrations and contaminant intakes. The previously derived risk-based cleanup goals were calculated using two exposure scenarios: a recreational use scenario (TetraTech, 1996) and a residential use scenario (Smith, 1995).

The DEQ/MWCB has provided a measure of the health risks to recreational populations exposed to mine wastes in a report titled "Risk-based Cleanup Guidelines for Abandoned Mine Sites" (TetraTech, 1996). These risk-based guidelines were developed using a risk assessment that assumed four types of recreation populations: fishermen, hunters, gold panners/rockhounds, and ATV/motorcycle riders. The maximum risk calculated for the applicable recreational exposure scenarios was for a gold panner/rockhound (waste rock and surface water exposures only) and a ATV/motorcycle rider (mill tailings only). A moderate level of recreational use was assigned, based on observations at the site and accessibility. The soil ingestion and dust inhalation exposure routes assumed a surface concentration equal to the average of the waste rock and tailings samples obtained in 1999. The water ingestion route assumed the maximum surface water concentrations in Frohner Meadows Creek downstream from the site, sampled in 1999, for drinking water. The assessment excludes the fish consumption route from the evaluation since surface water at the site exceeds acute standards; hence, fish consumption is not a viable exposure route for this site.

The residential use risk-based concentrations involve residential occupation of the contaminated land with the maximum level of exposure occurring for a child 0-6 years old (soil ingestion route). The resultant risk-based concentrations were derived for this worst-case residential exposure scenario by EPA Region III (Smith, 1995). The soil ingestion and dust inhalation exposure routes assumed surface concentrations equal to the average of the waste rock and tailings samples obtained in 1999 during the site characterization investigation. The drinking water ingestion route utilized a simple model to predict on-site groundwater concentrations with TCLP concentrations and HELP modeled groundwater flux.

5.1.3 Toxicity Assessment

The toxicity assessment examines the potential for the CoCs to cause adverse effects in exposed individuals and provides an estimate of the dose-response relationship between the extent of exposure to a particular contaminant and adverse effects. Adverse effects include both noncarcinogenic and carcinogenic health effects in humans. Sources of toxicity data include EPA's Integrated Risk Information System (IRIS), Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles, Health Effects Assessment Summary Tables (HEAST), and EPA criteria documents. Individual toxicity profiles for each CoC are not presented here; however, they are provided in the reference documents (Smith, 1995 and TetraTech, 1996). The existing risk-based concentrations that were used to characterize risks from exposure to the CoCs for each exposure scenario are presented in Tables 5-1 (residential scenario) and 5-2 (recreational scenario). The risk values correspond to a lifetime cancer risk of $1x10^{-6}$ (one in one million) or hazard quotients equal to 1.0.

TABLE 5-1
RISK-BASED CONCENTRATIONS FOR CONTAMINANTS OF CONCERN FOR THE RESIDENTIAL SCENARIO (SMITH, 1995)

CONTAMINANT OF CONCERN	RESIDENTIAL SOIL INGESTION (SOIL CONC.) mg/Kg	RESIDENTIAL DUST INHALATION (SOIL CONC.) mg/Kg	RESIDENTIAL WATER INGESTION µg/L
Antimony	31	NA	15
Arsenic	23 0.43 (Carc)	740,000 380 (Carc)	11 0.045 (Carc)
Silver	390	NA	180
Cadmium	39	140,000 920 (Carc)	18
Copper	3,100	NA	1,500
Mercury	23	0.31	11
Lead	400*	NA	15*
Zinc	23,000	NA	11,000

NA = Not Applicable, concentration is more than unity.
Carc = Carcinogenic.
*Lead levels derived from EPA recommendations, not RBC table (Smith, 1995).

TABLE 5-2
RISK-BASED CONCENTRATIONS FOR CONTAMINANTS OF CONCERN FOR THE RECREATIONAL SCENARIO, MODERATE USE (TETRATECH, 1996)

CONTAMINANT OF CONCERN	RECREATIONAL SOIL ING./INH.- WASTE ROCK mg/Kg	RECREATIONAL SOIL ING./INH.- TAILINGS mg/Kg	RECREATIONAL WATER INGESTION µg/L
Antimony	1,172	2,080	408
Arsenic	646 2.8 (Carc)	1,138 4.3 (Carc)	306 1.3 (Carc)
Silver	NA	NA	NA
Cadmium	3,500 43 (Carc)	6,300 78 (Carc)	512
Copper	108,400	193,200	37,800
Mercury	880	1,476	306
Lead	4,400	7,840	440
Zinc	880,000	NA	306,000

NA = Not Applicable, concentration is more than unity.
Carc = Carcinogenic.

5.1.4 Risk Characterization

5.1.4.1 Residential Land Use Scenario

The residential exposure assumptions utilized to estimate contaminant intakes were compared to the risk-based concentrations (RBCs) in Table 5-1. These data were used to calculate resultant human health noncarcinogenic Hazards Quotients (HQs) and carcinogenic risk values for each CoC. The results of the risk calculations for the residential land use scenario at the Frohner Mine Site are summarized in Table 5-3.

TABLE 5-3
SUMMARY OF NONCARCINOGENIC HAZARD QUOTIENTS (HQs)
AND CARCINOGENIC RISK VALUES FOR THE
RESIDENTIAL LAND USE SCENARIO - FROHNER MINE SITE

NONCARCINOGENIC HQ SUMMARY	SOIL INGESTION	WATER INGESTION	DUST INHALATION	TOTAL
Antimony	0.7129	0.0000	0.0000	0.7129
Arsenic	355.5652	0.9818	0.0111	356.5581
Cadmium	0.0718	0.0106	0.0000	0.0824
Copper	0.0308	0.0000	0.0001	0.0309
Lead	22.7325	43.3333	0.0091	65.0749
Mercury	0.0313	0.0073	0.1029	0.1414
Silver	0.1033	0.0000	0.0000	0.1034
Zinc	0.0096	0.0000	0.0002	0.0098
Total HQ - Noncarcinogenic	379.2574	43.3330	0.1234	**422.7138**
CARCINOGENIC RISK SUMMARY				
Arsenic	1.90E-02	2.40E-04	2.15E-05	1.93E-02
Cadmium	NC	NC	3.04E-09	3.04E-09
Total Risk – Carcinogenic	1.90E-02	2.40E-04	2.15E-05	**1.93E-02**

NC = Not Calculated because no RBC is provided.

HQ values exceed one for the residential land use scenario for two CoCs (As and Pb) via two exposure pathways (soil and water ingestion). HQ values greater than one indicate the potential for harmful effects by a CoC via the specified pathway. Soil ingestion of As and Pb, and water ingestion of Pb comprise the majority of the residential risk at the site.

The lower part of Table 5-3, carcinogenic risk, indicates that the residential exposure to CoCs (only As and Cd have carcinogenic RBCs) at the site results in a total carcinogenic risk of 1.93E-02. The EPA utilizes a 1.00E-06 value as a point of departure in assessing the need for contaminant cleanup at a particular site. The route specific risk values, which exceed 1.00E-06, are from As via: soil ingestion (1.90E-02), dust inhalation (2.15E-05), and water ingestion (2.40E-04).

5.1.4.2 <u>Recreational Land Use Scenario</u>

The recreational exposure assumptions utilized to estimate contaminant intakes were compared to the risk-based concentrations in Table 5-2. These data were used to calculate resultant human health carcinogenic risk values and noncarcinogenic HQs for each CoC. The results of the risk calculations for the recreational land use scenario at the Frohner Mine Site are summarized in Table 5-4.

TABLE 5-4
SUMMARY OF NONCARCINOGENIC HAZARD QUOTIENTS (HQs)
AND CARCINOGENIC RISK VALUES FOR THE
RECREATIONAL LAND USE SCENARIO - FROHNER MINE SITE

NONCARCINOGENIC HQ SUMMARY	SOIL INGESTION/ DUST INHALATION	WATER INGESTION	TOTAL
Antimony	0.0187	0.0105	0.0292
Arsenic	12.7417	0.0984	12.8400
Cadmium	0.0007	0.0102	0.0109
Copper	0.0009	0.0002	0.0011
Lead	2.0477	0.0366	2.0843
Mercury	0.0009	0.0002	0.0012
Silver	0.0000	0.0000	0.0000
Zinc	0.0003	0.0031	0.0034
Total HQ - Noncarcinogenic	14.8109	0.1592	14.9702
CARCINOGENIC RISK SUMMARY			
Arsenic	3.34E-03	9.53E-05	3.44E-03
Cadmium	5.91E-08	NC	5.91E-08
Total Risk – Carcinogenic	3.34E-03	9.53E-05	3.44E-03

NC = Not Calculated because no RBC is provided.

Inspection of the HQs on Table 5-4 yields the following observations. First, HQ values exceed one for the recreational land use scenario for two CoCs (As and Pb) via one evaluated exposure route (soil ingestion/dust inhalation). HQ values greater than one indicate the potential for harmful effects by a CoC via the specified pathway(s). Secondly, the As HQ value of 12.7 and the Pb HQ value of 2.05 via the soil/dust route comprise the majority of the total noncarcinogenic HQ and this value is greater than one. The soil/dust pathway total HQ of 14.8 indicates that this exposure pathway presents the greatest likelihood of adverse human health effects for this scenario and these effects are likely since the HQ is greater than one.

The lower part of Table 5-4, carcinogenic risk, reveals that the recreational exposure to CoCs (only As and Cd have RBCs) at the site results in a total carcinogenic risk of 3.44E-03, which exceeds one per million (1.00E-06) exposed individuals by more than three orders of magnitude.

The EPA utilizes this 1.00E-06 value as a point of departure in assessing the need for contaminant cleanup at a particular site. The carcinogenic risk estimates for As of 3.34E-03 via soil ingestion/dust inhalation and 9.53E-05 via water ingestion are, therefore, of concern. The primary pathway and carcinogenic CoC is As via soil ingestion/dust inhalation, with water ingestion of As a significant secondary pathway; reclamation alternatives should focus on addressing these exposure pathways for the mitigation of human health exposures.

5.2 ECOLOGICAL RISK ASSESSMENT

5.2.1 Introduction

The ecological risk assessment was performed for the Frohner Mine Site following Federal RI/FS guidance for CERCLA (Superfund) sites (EPA, 1988a). The key guidance documents used were EPA's Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual (EPA, 1989b), and Ecological Assessment of Hazardous Waste Sites (EPA, 1989c). The waste materials present at the site pose a potential risk not only to humans, but also to other species that come into contact with them. Due to the sparse and indirect nature of the ecologic risk data available for the site, this evaluation is intended as a screening-level ecological risk assessment, and the results are of a qualitative nature.

The ecological risk assessment estimates the effects of taking no action at the site and involves four steps: 1) identification of contaminants and ecologic receptors of concern; 2) exposure assessment; 3) ecologic effects assessment; and 4) risk characterization. These four tasks are accomplished by evaluating available data and selecting contaminants, species and exposure routes of concern, estimating exposure point concentrations and intakes, assessing ecologic toxicity of the CoCs, and characterizing overall risk by integrating the results of the toxicity and exposure assessments.

Problems at the Frohner Mine Site that could impact ecologic receptors include elevated concentrations of metals and As in waste materials, and elevated concentrations of metals and As in surface water and stream sediments. The easily accessible waste materials may result in significant ecological effects; the objective of this ecological risk assessment are to estimate current and future effects of implementing the no-action alternative at the site.

5.2.2 Contaminants and Receptors of Concern

As in the human health risk assessment, contaminants that are significantly above background concentrations and are associated with the site are retained as CoCs. Out of the 11 metals analyzed, 8 are present at the site at concentrations significantly above background levels, with 20% of the samples detected above the corresponding detection limit: As, Ag, Cd, Cu, Hg, Pb, Sb, and Zn. These constituents are selected for evaluation because they are present in significant concentrations in wastes, stream sediments, and surface water. However, several of these contaminants have no ecologic toxicity data with which to evaluate potential effects.

Two groups of ecologic receptors have been identified as potentially affected by site contamination. The first group of receptors are those associated with Frohner Meadows Creek and its receiving stream Lump Gulch downstream from the site, and includes fisheries, aquatic life, and wetlands. Although Frohner Meadows Creek does not actively support a viable fishery, it discharges to Lump Gulch (1.5 miles downstream of the site), which is a recreational fishery. Wetlands of any size are of concern because they typically support a diverse ecologic community. These surface water receptors are evaluated using EPA aquatic life criteria, which apply to aquatic organisms only; there are no criteria with which to evaluate wetlands.

The second group of receptors are native terrestrial plant communities, which are notably absent on many of the wastes at the site. They are of concern because native vegetation has not become established on the wastes, which would help reduce the potential for entrainment of wastes into surface water and reduce exposure to the wastes by human and wildlife receptors.

5.2.3 Exposure Assessment

The two exposure scenarios can be semi-quantitatively assessed. Both the surface water-aquatic life and plant-phytotoxicity scenarios can be compared directly to toxicity standards that apply to the respective environmental media.

5.2.3.1 Surface Water/Sediment - Aquatic Life Scenario

Ecologic exposures via this pathway are threefold: direct exposure of aquatic organisms to surface water concentrations that exceed toxicity thresholds; ingestion of aquatic species (e.g., insects) that have bioaccumulated contaminants to the extent that they are toxic to the predator (e.g., fish); and exposure of aquatic organisms (e.g., fish embryos) to sediment pore water environments that are toxic due to elevated contaminant concentrations in the sediments. Data used for this assessment were collected in Frohner Meadows Creek (sediment and surface water) during 1999.

5.2.3.2 Plant - Phytotoxicity Scenario

This scenario involves the limited ability of various plant species to grow in soils or wastes with high concentrations of site-related contaminants.

5.2.4 Ecological Effects Assessment

The known effects of the site CoCs are available from several literature sources and are not repeated here. No site-specific toxicity tests were performed to support the ecologic risk assessment, either in-situ or at a laboratory. Only existing and proposed toxicity-based criteria and standards were used for this ecological effects assessment.

5.2.4.1 Surface Water/Sediment - Aquatic Life Scenario

Freshwater acute (1-hour average) water quality criteria have been promulgated by EPA for many of the CoCs. Several of these criteria are calculated as a function of water hardness and a few are numerical standards. These water quality standards are presented in Table 5-5 and apply to Frohner Meadows Creek downstream from the site.

TABLE 5-5
WATER QUALITY CRITERIA

ACUTE CRITERIA IN μg/L	As	Ag	Cd	Cu	Pb	Zn
Frohner Meadows Creek	360	0.9	1.7	8.7	31.4	62

Presently, EPA has not finalized sediment quality criteria. Proposed sediment criteria for metals currently consist of the Effect Range - Low (ER-L) and Effect Range - Median (ER-M) values generated from the pool of national freshwater and marine sediment toxicity information (Long and Morgan, 1991). The ER-M values are probably most appropriate to use for comparison to Frohner Meadows Creek sediment data, and are presented on Table 5-6.

TABLE 5-6
SEDIMENT QUALITY CRITERIA (PROPOSED)

CRITERIA IN mg/Kg	As	Cd	Cu	Pb	Zn
Effect Range - Median (ER-M)	85	9	390	110	270

5.2.4.2 Plant - Phytotoxicity Scenario

Information is available on the phytotoxicity for some of the CoCs (Kabata-Pendias and Pendias, 1989) and these are listed in Table 5-7. The availability of contaminants to plants and the potential for plant toxicity depends on many factors including soil pH, soil texture, nutrients, and plant species.

TABLE 5-7
SUMMARY OF PHYTOTOXIC SOIL CONCENTRATIONS

	As	Cd	Cu	Pb	Zn
Concentration Range (mg/Kg, dry wt.)	15-50	3-8	60-125	100-400	70-400

5.2.5 Risk Characterization

This section combines the ecologic exposure estimates and concentrations and the ecologic effects data to provide a screening level estimate of potential adverse ecologic impacts for the three scenarios evaluated. This was accomplished by generating ecologic impact quotients (EQs), analogous to the health HQs calculated for human exposures to noncarcinogens. CoC-specific EQs were generated by dividing the particular intake estimate or concentration by available ecological effect values or concentrations. As with HQs, if EQs are less than one, adverse ecological impacts are not expected at the Frohner Mine Site.

5.2.5.1 Surface Water/Sediment - Aquatic Life Scenario

For this scenario, surface water concentration data are compared to acute aquatic life criteria. Limitations of this comparison include that the EPA water quality criteria are not species-specific toxicity levels. They represent toxicity to the most sensitive species, which may or may not be present at the Frohner Mine Site, and toxicity to the most sensitive species may not in itself be a limiting factor for the maintenance of a healthy, viable fishery and/or other aquatic organisms. The results of the EQ calculations for this scenario are presented in Table 5-8.

TABLE 5-8
ECOLOGIC IMPACT QUOTIENTS (EQs) FOR THE SURFACE WATER - AQUATIC LIFE SCENARIO

LOCATION	As	Cd	Cu	Pb	Ag	Zn
Frohner Meadows Creek	0.084	3.092	0.938	0.513	0.833	15.482

Examination of Table 5-8 indicates EQ values are all below one with the exception of Cd and Zn. These two contaminants have the potential for acute aquatic life impacts in Frohner Meadows Creek.

Similarly, stream sediment concentration data are compared to proposed sediment quality criteria (Median Effect Range). Limitations of this comparison include that these sediment quality criteria are preliminary and are also not species-specific. They represent sediment toxicity to the most sensitive species, which may or may not be present at the Frohner Mine Site, and toxicity to the most sensitive species may not in itself be a limiting factor for the maintenance of a healthy, viable fishery and/or other aquatic organisms. The results of these EQ calculations are presented in Table 5-9.

TABLE 5-9
ECOLOGIC IMPACT QUOTIENTS (EQs) FOR THE SEDIMENT - AQUATIC LIFE SCENARIO

LOCATION	As	Cd	Cu	Pb	Zn
Frohner Meadows Creek	11.176	0.856	0.138	9.545	2.352

The EQs presented in Table 5-9 indicate the potential for aquatic life impacts (EQs greater than 1) due to apparent sediment toxicity for As, Pb, and Zn in Frohner Meadows Creek. The elevated and persistent EQs for As, Pb, and Zn suggest that these contaminants have the potential to adversely affect sediment benthos, fish embryos, and/or macroinvertebrate communities. However, the sediment criteria used to calculate these EQs may not apply to species found in this system.

5.2.5.2 Plant - Phytotoxicity Scenario

Source area average concentrations collected at the Frohner Mine Site are compared to high values of the range of plant phytotoxicity derived from the literature. Limitations of this comparison include that the phytotoxicity ranges are not species-specific; they represent toxicity to species, which may or may not be present at the site. Additionally, other physical characteristics of the waste materials may create microenvironments, which limit growth and survival of terrestrial plants directly or in combination with substrate toxicity. Waste materials are likely to have poor water holding capacity, low organic content, limited nutrients, and may harden enough to resist root penetration. The results of the EQ calculations for this scenario are presented in Table 5-10.

TABLE 5-10
ECOLOGIC IMPACT QUOTIENTS (EQs) FOR THE PLANT - PHYTOTOXICITY SCENARIO

	As	Cd	Cu	Pb	Zn
Frohner Mine and Mill – Average	163.56	0.35	0.76	22.73	0.55

The EQs presented in Table 5-10 indicate the potential for adverse ecologic impacts to plant communities for the Frohner Mine Site. The calculated EQs greater than one include: As and Pb. The non-conservative assumption of using the high end of the phytotoxicity range to derive these EQs, probably underestimates the potential phytotoxic effect to the plant community. However, several other factors in addition to phytotoxicity combine to adversely affect plant establishment and success on the waste materials.

5.2.6 Risk Characterization Summary

The calculated EQs can be used to assess whether ecologic receptors are exposed to potentially harmful doses of site-related contaminants via the three ecologic scenarios evaluated. The EQs for each of the three scenarios at the Frohner Mine Site are presented in Table 5-11 to estimate a combined ecologic EQ for each scenario and each contaminant. The results of combining the ecologic scenarios are also summarized in Table 5-11.

TABLE 5-11
SUMMARY OF ECOLOGIC IMPACT QUOTIENT (EQ)
VALUES FOR THE FROHNER MINE SITE

ECOLOGIC EQ SUMMARY	SURFACE WATER	SEDIMENT	PLANT TOXICITY	TOTAL
Arsenic	0.084	11.177	163.56	174.82
Cadmium	3.092	0.856	0.35	4.30
Copper	0.938	0.138	0.76	1.84
Lead	0.513	9.545	22.73	32.79
Silver	0.833	NC	NC	0.83
Zinc	15.482	2.352	0.55	18.391
Total EQ	20.973	24.067	187.96	233.00

NC = Not Calculated because no applicable standard exists.

The aquatic life scenario results in EQs as high as 15.5 (surface water - Zn), and 11.2 (sediments - As) in Frohner Meadows Creek. The plant toxicity EQs are as high as 163 (As). These EQs show that even at the lower bound of these calculated risk estimates, the ecologic risk characterization demonstrates that contaminants at the site constitute a probable adverse ecologic effect via all three exposure scenarios and justify appropriate cleanup. As is the primary CoC, and the plant community and aquatic life are the primary receptors; Zn in surface water and Pb and Zn in sediment are secondary contaminants and receptors of concern.

6.0 RECLAMATION OBJECTIVES AND GOALS

The primary objective of the Frohner Mine Site reclamation project is to protect human health and the environment in accordance with the guidelines set forth by the NCP. Specifically, the remedy selected must limit human and environmental exposure to the CoCs and reduce the mobility of those contaminants to reduce impacts to the local surface water and groundwater resources.

6.1 ARAR-BASED RECLAMATION GOALS

6.1.1 Groundwater

The groundwater at the Frohner Mine Site is not currently used for a drinking water source; however, it may be a potential drinking water source in the future. Also, groundwater at the site most likely discharges to surface water. Based on the risk assessment and modeled exceedances of standards, the only groundwater CoC at the site is Pb.

ARAR-based reclamation goals are most often the MCLs, non-zero maximum contaminant level goals (MCLGs), or state drinking water HHSs, whichever are more stringent. Potential ARAR-based reclamation goals for the groundwater medium are presented in Table 6-1. Although direct groundwater treatment/remediation is not within the scope of actions under consideration at the site as part of this removal action EEE/CA, removing source material will affect groundwater contaminant concentrations.

TABLE 6-1
ARAR-BASED RECLAMATION GOALS FOR GROUNDWATER (µg/L)

CHEMICAL	TYPE	CONCENTRATION
Lead	**HHS**	15 µg/L

Source: HHS - Human Health Standards for Surface Water (MDEQ/WQB, 1998).

6.1.2 Surface Water

AALS and HHSs are common ARARs for the surface water medium. The more stringent of the two standards is identified as the ARAR-based remediation goal; acute rather than chronic aquatic life standards are appropriate since long-term monitoring data are not available. The surface water is being evaluated for future aquatic life use rather than for a current or potential source of drinking water. The only contaminants of concern at the site are Cd and zinc. Table 6-2 presents the ARAR-based reclamation goals for surface water.

TABLE 6-2
ARAR-BASED RECLAMATION GOALS FOR
SURFACE WATER (µg/L)

CHEMICAL	TYPE	CONCENTRATION
Cadmium	**AALS**	1.7 µg/L @ 47 mg/L hardness
Zinc	AALS	62 µg/L @ 47 mg/l hardness

Source: AALS - Freshwater Acute Aquatic Life Standards (MDEQ/WQB, 1998).

6.1.3 Soil

Chemical-specific ARARs are not available at this time for the soil medium.

6.2 RISK-BASED CLEANUP GOALS

Previously calculated risk-based cleanup goals for both the carcinogenic and noncarcinogenic estimates of human health risk are applied for two land-use scenarios at the Frohner Mine Site, recreational and residential. These concentrations were derived using exposure assumptions contained in other documents (residential-Smith, 1995 and recreational-TetraTech, 1996) and are the same as those presented in Section 5.1. Both sets of cleanup goals attempt to reduce the risk of excess incidence of cancer to 1.0E-06 (EPA, 1990) and the noncarcinogenic HQ to #1 (EPA, 1989a). Both sets of cleanup goals are presented in Table 6-3.

TABLE 6-3
PROPOSED CLEANUP GOALS FOR THE FROHNER MINE SITE

CONTAMINANT OF CONCERN	RECREATIONAL SOIL ING./INH. WASTE ROCK mg/Kg	RECREATIONAL WATER INGEST. (SURFACE WATER) µg/L	RESIDENTIAL SOIL INGESTION mg/Kg	RESIDENTIAL WATER INGEST. (GROUNDWATER) µg/L
Antimony	1,172	408	31	15
Arsenic	646 2.8 (Carc.)	306 1.3 (Carc.)	23 0.43 (Carc.)	11 0.045 (Carc.)
Cadmium	3,500	512	39	18
Copper	108,400	37,800	3,100	1,500
Lead	2,200	440	400*	15*
Silver	NA	NA	390	180
Zinc	440,000	306,000	23,000	11,000

NA = Not Applicable, concentration is more than unity.
* Used USEPA recommendations, not RBC table, from Smith, 1995.

Risk reduction required to attain noncarcinogenic human health and ecologic reclamation goals for each CoC (by each pathway) is shown on Table 6-4.

TABLE 6-4
RISK REDUCTION NECESSARY TO ATTAIN NONCARCINOGENIC HUMAN HEALTH AND ECOLOGIC CLEANUP GOALS

PATHWAY	RISK REDUCTION REQUIRED (%)				
	As	**Cd**	**Cu**	**Pb**	**Zn**
Human Health Exposure Pathways:					
Soil Ingestion (Res.)	99.7	--	--	95.6	--
Water Ingestion (Res.)	--	--	--	97.6	--
Soil Ing./Inh. (Recr.)	92.2	--	--	51.2	--
Water Ingestion (Recr.)	--	--	--	--	--
Ecologic Exposure Pathways:					
Surface Water	--	67.7	--	--	93.5
Sediments	91.1	--	--	89.5	57.5
Plant Phytotoxicity	99.4	--	--	95.6	--

-- = Risk reduction not required for the contaminant for that pathway.

7.0 DEVELOPMENT AND SCREENING OF RECLAMATION ALTERNATIVES

The contaminated waste sources located at the Frohner Mine Site can be categorized based upon their physical and chemical characteristics. To facilitate the evaluation of potentially applicable reclamation technologies, these media can be divided into three general categories based on physical and chemical characteristics. The three categories include:

- tailings;
- waste rock dumps; and
- mine drainage (adit/seep discharge).

Treatment of these various media is dependent on the concentration of metal contaminants in the media, as well as the physical characteristics of the media. The potential applicability of a technology is dependent on the interrelationship of reclamation technologies and the volume of material requiring treatment. A brief definition of each contaminated medium category follows.

Tailings - Dry or alternately wet and dry tailings/waste tend to contain oxidized forms of metals. These oxidized metals are easily mobilized during precipitation (infiltration) or high run-off events. Dry tailings are located in the Frohner Meadows Creek Drainage at the site. Fine-grained materials eroded from waste piles are present in the floodplain at the site and behave similarly to tailings materials.

Waste Rock Dumps - Consist of overburden and gangue materials that generally do not contain sufficient economic quantities of target metals for recovery. The dumps contain non-mineralized and low-grade mineralized rock removed from areas adjacent to the ore and placed in piles close to the mine. The nature and extent of the mineralization, climatic conditions, and buffering capacity of the foundation soil determine the potential of the material to impact water quality.

In general, waste rock dumps contain oxidizing sulfide minerals and are subject to percolation of precipitation and run-off. The sulfide minerals within the dump may react with percolating water in the presence of oxygen to form sulfuric acid; however, the ABA data collected from the Frohner Mine Site indicate that the waste materials may form significant quantities of sulfuric acid. Migration of sulfuric acid through the dumps results in the further mobilization of solubilized metal oxides. A total of seven waste rock dumps of various sizes and one tailings pile are located at the Frohner Mine Site; one of these dumps and the tailings pile are located directly in or near the floodplain of Frohner Meadows Creek. Locations of the waste rock dumps at the sites are shown on Figure 3-1.

Mine Drainage (Adit/Seepage Water Discharge) - Water draining from underground mine workings often exhibits elevated concentrations of heavy metals and low (acidic) pH conditions due to chemical reactions that occur when the water comes in direct contact with soluble mineralized rock and oxygen. The discharging adits at both the Frohner Mine Site contain significantly elevated concentrations of several metals. The discharge flow rates vary significantly with seasonal and climatic variations. Locations of the adit discharges and seeps are shown on Figures 3-1 and 3-2.

7.1 IDENTIFICATION AND SCREENING OF RECLAMATION TECHNOLOGIES AND PROCESS OPTIONS

The purpose of identifying and screening technology types and process options is to eliminate those technologies that are obviously unfeasible, while retaining potentially effective options. General response actions are progressively refined into technology types and process options. The process options are screened, and those retained are used to develop reclamation alternatives. General response actions, technology types, and process options are briefly discussed in this section.

General response actions and process options are evaluated for contaminated solid media and mine water discharge only. No evaluation has been conducted for surface water, groundwater, or off-site stream sediments. This decision was based primarily on the presumption that remediating the contamination at the source(s) will subsequently reduce/eliminate the problems associated with these other environmental media. General response actions potentially capable of meeting the reclamation objectives are identified in Table 7-1. Response actions include No Action, Institutional Controls, Engineering Controls, Excavation and Treatment, and Insitu Treatment for the solid media and institutional, passive, active, source, and biological treatment for the mine water discharge. Table 7-2 contains the screening rationale that was used to eliminate or retain the various reclamation process options for potential application at the Frohner Mine Site.

In Section 7.2 feasible technologies are combined and several reclamation alternatives are presented and subjected to an initial/preliminary screening based on effectiveness, implementability, and cost. The purpose of the initial screening of alternatives is to identify those alternatives appropriate for a subsequent, detailed analysis. Detailed analyses of alternatives, which pass the initial screening, are presented in Section 8.0. The initial screening also helps identify technology-(process option) specific data needs for detailed site characterization as well as needs for possible treatability studies.

7.1.1 No Action

Under the no action option, no future reclamation or monitoring would occur at the site. The no action response is a stand-alone response that is used as a baseline against which candidate reclamation alternatives are compared.

7.1.2 Institutional Controls

Potentially applicable institutional controls consist of land use and access restrictions. Land use restrictions would limit the potential future uses for the land in the event of a sale. Limitations may be applicable in the case of no action, on-site disposal, capping in place, or other reclamation alternatives that would result in leaving contaminated material on-site that could be compromised by future activities. Institutional controls that are developed as part of an alternative are enforced by the USFS. Therefore, the USFS must be involved in the development and eventual implementation of an institutional control.

TABLE 7-1
GENERAL RESPONSE ACTIONS, TECHNOLOGY TYPES, AND PROCESS OPTIONS FOR CONTAMINATED SOLID MEDIA AT THE FROHNER MINE SITE

GENERAL RESPONSE ACTION	TECHNOLOGY TYPE	PROCESS OPTIONS
No Action	Not Applicable	Not Applicable
Institutional Controls	Access Restrictions	Fencing Land Use Control
Engineering Controls	Containment	Soil Cover Multimedia Cover Asphalt/Concrete Cover
	Surface Controls	Consolidation Grading Revegetation Erosion Protection Run-on/Run-off Control
	On-Site Disposal	RCRA Repository Solid Waste Repository
	Off-Site Disposal	RCRA Landfill Solid Waste Landfill Permitted Tailings Facility
Excavation and Treatment	Fixation/Stabilization	Pozzolan/Cement Based
	Reprocessing	Milling/Smelter
	Physical/Chemical Treatment	Soil Washing Acid Extraction Alkaline Leaching
	Thermal Treatment	Fluidized Bed Reactor Rotary Kiln Multi-Hearth Kiln Vitrification
Insitu Treatment	Physical/Chemical Treatment	Stabilization/Solidification Soil Flushing
	Thermal Treatment	Vitrification

Institutional controls involve implementing access restrictions, such as fencing and land use control. These restrictions are implemented to preclude the future development of impacted areas or to protect an implemented remedy. This type of action does not, in itself, achieve a specific clean-up goal. However, institutional controls will be considered as additive measures to accompany other reclamation alternatives.

7.1.3 Engineering Controls

Engineering controls are used primarily to reduce the mobility of contaminants by creating a barrier that prevents transport of waste from the contaminated source to the surrounding media. Engineering controls do not reduce the volume or toxicity of the hazardous material. Engineering controls typically applied include containment/capping, revegetation, run-on/run-off control, and/or disposal.

7.1.3.1 Containment

Containment technologies are used as source control measures to divert surface water from the contaminated media, to minimize infiltration (and subsequent formation of leachate) of surface water/precipitation into the underlying contaminated media by increasing evapotranspiration processes, and to reduce the potential health risk that may be associated with exposure (direct contact or airborne releases of particulate) to the contaminated media. The cap or cover design is a function of the degree of hazard posed by the contaminated media and may vary in complexity from a simple soil cover to a multi-layered RCRA cap. RCRA cap performance standards are included in 40 CFR 264.310, which addresses RCRA landfill closure requirements. These performance standards may not always be appropriate, particularly in instances where the toxicity of the contaminated media is relatively low, where the cap is intended to be temporary, where there is low precipitation, or where the waste is not leached by infiltrating rain water. Specific cap construction is partially driven by the desired land use following cap construction.

Capping is appropriate whenever contaminated materials are to be left in place at a site, such as when total excavation and removal or treatment would be cost prohibitive. Capping is considered to be a standard construction practice. Equipment and construction methods associated with capping are readily available, and design methods and requirements are well understood.

7.1.3.2 Surface Controls

Similar to containment, surface control measures are used primarily to reduce contaminant mobility. Surface controls may be appropriate in more remote areas where direct human contact is not a primary concern (human receptors not living or working directly on or near the site). Surface control process options include consolidation, grading, revegetation, and erosion protection. These process options are usually integrated as a single reclamation alternative.

Consolidation involves grouping similar waste types in a common area for subsequent management or treatment. Consolidation is especially applicable when multiple waste sources are present at a site and one or more of the sources require removal from particularly sensitive areas (i.e., floodplain, residential area, or heavy traffic area) or when treating one large combined waste source in a particular location rather than several smaller waste sources dispersed throughout an area.

Grading is the general term for techniques used to reshape the ground surface to reduce slopes, to manage surface water infiltration and run-off, and to aid in erosion control. The spreading and compaction steps used in grading are routine construction practices. The equipment and methods used in grading are similar for all surfaces, but will vary slightly depending upon the waste type and the surrounding terrain. Periodic maintenance and regrading may be necessary to eliminate depressions formed as a result of settlement/subsidence or erosion.

Revegetation involves adding soil amendments to the waste's surface to provide nutrients, organic material, and neutralizing agents and/or to improve the water storage capacity of the contaminated media, as necessary. This action will establish native vegetative species to provide an erosion-resistant ground surface that helps protect the ground surface from surface water and wind erosion, and reduces net infiltration through the contaminated media by increasing evapotranspiration processes. In general, revegetation includes the following steps: 1) selecting appropriate plant species; 2) preparing seedbed, which may include deep application of soil amendments as necessary; 3) seeding/planting; 4) mulching and/or chemical stabilization; and 5) fertilizing and maintenance.

Erosion protection includes using erosion resistant materials, such as mulch, natural or synthetic fabric mats, riprap, and/or surface water diversion ditches, to reduce the erosion potential at the contaminated media's surface. The erosion resistant materials are placed in areas susceptible to surface water erosion (concentrated flow or overland flow) or wind erosion. Proper erosion protection design requires knowledge of drainage area characteristics, average slopes, soil texture, vegetation types and abundance, and precipitation data.

7.1.3.3 <u>On-Site Disposal</u>

Permanent on-site disposal is used as a source control measure. On-site disposal involves placing the contaminated media in an engineered containment facility located within the site boundary. On-site disposal options may be applied to pre-treated or untreated contaminated materials. The design configuration of an on-site repository would depend on the toxicity and type of material requiring disposal. The design could range in complexity from a relatively simple, unlined and covered impoundment, to a double-lined impoundment equipped with double leachate collection systems and RCRA-type cap. Materials failing to meet the TCLP criteria may require disposal in a repository conforming to the performance standards for a RCRA landfill closure.

7.1.3.4 <u>Off-Site Disposal</u>

Off-site disposal involves placing excavated contaminated material in an engineered containment facility located outside the site boundary. Off-site disposal options may be applied to pre-treated or untreated contaminated materials and would depend on TCLP results. Materials failing to meet the TCLP criteria would require disposal in a RCRA-permitted treatment, storage, and disposal (TSD) facility. Conversely, less toxic materials could possibly be disposed of in an off-site permitted sanitary landfill or mine waste permitted landfill in compliance with other applicable laws.

7.1.4 Excavation and Treatment

Excavation and treatment incorporates the removal of contaminated media and subsequent treatment via a specific treatment process that chemically, physically, or thermally results in a reduction of contaminant toxicity and/or volume. Treatment processes have the primary objective of either: 1) concentrating the metal contaminants for additional treatment or recovery of valuable constituents; or 2) reducing the toxicity of the hazardous constituents.

Excavation can be completed using conventional earth-moving equipment and accepted hazardous materials handling procedures. Precautionary measures, such as stream diversion or isolation, would be necessary for excavating materials contained in the floodplain of a stream. Containment and/or treatment of water encountered during excavation may also be necessary.

7.1.4.1 Fixation/Stabilization

Fixation/stabilization technologies are used to treat materials by physically encapsulating them in an inert matrix (stabilization) and/or chemically altering them to reduce the mobility and/or toxicity of their constituents (fixation). These technologies generally involve mixing materials with binding agents under prescribed conditions to form a stable matrix. Fixation/stabilization is an established technology for treating inorganic contaminants. The technology incorporates a reagent or combination of reagents to facilitate a chemical and/or physical reduction of the mobility of contaminants in the solid media. Lime/fly, ash-based treatment processes and pozzolan/cement-based treatment processes are potentially applicable fixation/stabilization technologies.

7.1.4.2 Reprocessing

Reprocessing involves excavating and transporting the waste materials to an existing permitted mill or smelter facility for processing and economic recovery of target metals. Applicability of this option depends on the willingness of an existing permitted facility to accept and process the material and dispose of the waste. Although reprocessing at active facilities has been conducted in the past, permit limitations, CERCLA liability, and process constraints all limit the feasibility of this process option.

7.1.4.3 Physical/Chemical Treatment

Physical treatment processes use physical characteristics to concentrate constituents into a relatively small volume for disposal or further treatment. Chemical treatment processes treat contaminants through adding a chemical reagent that removes or fixates the contaminants. The net result of chemical treatment processes is a reduction of toxicity and/or mobility of contaminants in the solid media. Chemical treatment processes often work in conjunction with physical processes to wash the contaminated media with water, acids, bases, or surfactants.

Potentially applicable physical/chemical treatment process options include: soil washing, acid extraction, and alkaline leaching.

Soil washing is an innovative treatment process, which consists of washing the contaminated media (with water) in a heap, vat, or agitated vessel to dissolve water soluble contaminants. Soil washing requires that contaminants be readily soluble in water and small enough so that dissolution can be achieved in a practical retention time. Dissolved metal constituents contained in the wash solution are precipitated as insoluble compounds, and the treated solids are de-watered before additional treatment or disposal. The precipitates form a sludge, which would require additional treatment, such as de-watering or stabilization before disposal.

Acid extraction applies an acidic solution to the contaminated media in a heap, vat, or agitated vessel. Depending on temperature, pressure, and acid concentration, varying quantities of the metal constituents present in the contaminated media would be solubilized. A broader range of contaminants can be expected to be acid soluble at ambient conditions using acid extraction versus soil washing; however, sulfide compounds may only be acid soluble under extreme conditions of temperature and pressure. Dissolved contaminants are subsequently precipitated for additional treatment and/or disposal.

Alkaline leaching is similar to acid extraction in which a leaching solution (in this case ammonia, lime, or caustic soda) is applied to the contaminated media in a heap, vat, or agitated vessel. Alkaline leaching is potentially effective for leaching the majority of metals from the contaminated media; however, the removal of As is not well documented.

7.1.4.4 Thermal Treatment

Under thermal treatment technologies, heat is applied to the contaminated media to volatilize and oxidize metals and render them amenable to additional processing and/or to vitrify the contaminated media into a glass-like, non-toxic, non-leachable matrix. Potentially applicable moderate temperature thermal processes, which volatilize metals and form metallic oxide particulates, include the fluidized bed reactor, the rotary kiln, and the multi-hearth kiln. Potentially applicable high temperature thermal treatment processes include vitrification. All components of the contaminated media are melted and/or volatilized under high temperature vitrification. Volatile contaminants and gaseous oxides of sulfur are driven off as gases in the process, and the non-volatile, molten material containing contaminants is cooled, and in the process, vitrified.

Thermal treatment technologies can be applied to wet or dry contaminated media; however, the effectiveness may vary somewhat with variable moisture content and particle size. Crushing may be necessary as a pre-treatment step, especially for large and/or variable particle sizes, such as in waste rock dumps. Moderate temperature thermal processes should only be considered as pretreatment for other treatment options. This process concentrates the contaminants into a highly mobile (and potentially more toxic) form. High temperature thermal processes immobilize most metal contaminants into a vitrified slag, which have to be properly disposed. The volatile metals would be removed and/or concentrated into particulate metal oxides, which would likely require disposal as hazardous waste. Thermal treatment costs are extremely high compared to other potentially applicable reclamation technologies.

7.1.5 Insitu Treatment

Insitu treatment involves treating the contaminated media in place. Insitu technologies reduce the mobility and toxicity of the contaminated media and may reduce worker exposure to the contaminated materials; however, insitu technologies allow a lesser degree of control, in general, than exsitu treatment options.

7.1.5.1 Physical/Chemical Treatment

Potentially applicable insitu physical/chemical treatment technologies include stabilization/ solidification and soil flushing.

Insitu stabilization/solidification is similar to conventional stabilization in that a solidifying agent (or combination of agents) is used to create a chemical or physical change in the mobility and/or toxicity of the contaminants. The insitu process uses deep mixing techniques to allow maximum contact of the solidifying agents with the contaminated media.

Soil flushing is an innovative process that injects an acidic or basic reagent or chelating agent into the contaminated media to solubilize metals. The solubilized metals are extracted using established dewatering techniques, and the extracted solution is then treated to recover metals or is disposed as aqueous waste. Low permeability materials may hinder proper circulation, flushing solution reaction, and ultimate recovery of the solution. Currently, soil flushing has only been demonstrated at pilot scale.

7.1.5.2 Thermal Treatment

Insitu vitrification is an innovative process used to melt contaminated solid media in place to immobilize metals into a glass-like, inert, non-leachable solid matrix. Vitrification requires significant energy to generate sufficient current to force the solid media to act as a continuous electrical conductor. This technology is seriously inhibited by high-moisture content. Gases generated by the process must be collected and treated in an off-gas treatment system. Insitu vitrification has only been demonstrated at pilot scale, and treatment costs are extremely high compared to other treatment technologies.

7.2 IDENTIFICATION OF ALTERNATIVES - FROHNER MINE SITE

In this section, the remaining remedial technology types and associated process options that passed the initial screening are assembled into reclamation alternatives for the Frohner Mine Site. For the purposes of defining reclamation alternatives at this stage, the solid media (tailings, waste rock and disturbed soils, SSTs, and intermixed mine waste) and physical hazards (shafts) are addressed independently. Table 7-3 presents the preliminary reclamation alternatives that have been identified for the solid media at the site.

TABLE 7-3
RECLAMATION ALTERNATIVES FOR THE WASTE ROCK DUMPS AND TAILINGS AT THE FROHNER MINE SITE

ALTERNATIVE	DESCRIPTION
Alternative #1:	No Action
Alternative #2:	Institutional Controls
Alternative #3a:	Partial In-Place Containment of Wastes (WR1, WR2, WR5, and WR6) and Partial Waste Consolidation (WR3, WR4, WR7, TP1, and SSTs) with a Cover Soil Cap
Alternative #3b:	Partial In-Place Containment of Wastes (WR1, WR2, WR5, and WR6) and Partial Waste Consolidation (WR3, WR4, WR7, TP1, and SSTs) with a Multi-Layered Lined Cap
Alternative #4a:	Complete Removal/Disposal of Solid Media in an On-Site Constructed Modified RCRA Repository (bottom liner with multi-layered cap)
Alternative #4b:	Complete Removal/Disposal of Solid Media in an On-Site Constructed Modified RCRA Repository (no bottom liner with multi-layered cap)
Alternative #5a:	Partial Removal/Disposal of Solid Media On-Site in a Constructed Modified RCRA Repository (WR7, TP1, and SSTs) [bottom liner with multi-layered cap] and Partial In-Place Containment (WR1-6)
Alternative #5b:	Partial Removal/Disposal of Solid Media On-Site in a Constructed Modified RCRA Repository (WR7, TP1, and SSTs) [no bottom liner with multi-layered cap] and Partial In-Place Containment (WR1-6)
Alternative #5c:	Partial Removal/Disposal of Solid Media On-Site in a Constructed Modified RCRA Repository (WR3, WR7, TP1, and SSTs) [no bottom liner with multi-layered cap] and Partial In-Place Containment (WR1, WR2, WR4, WR5, WR6)
Alternative #6:	Complete Removal to Luttrell Pit
Alternative #7:	Removal/Treatment/Disposal at a Permitted Off-Site Hazardous Waste Disposal Facility

It should be noted that the solid media alternative selected will have impact on the contaminated aqueous media. In other words, the two media cannot be considered independently. It is conceivable that the solid media alternative selected will make no further action necessary for the contaminated aqueous media. After implementing a reclamation action for the solid media, reclamation goals for the aqueous media may be attained. A solid media alternative must be selected and implemented to determine if the previous actions directed at the aqueous media are effective enough to meet reclamation goals. Therefore, this EEE/CA is focused primarily on the development, evaluation, and selection of solid media alternatives.

7.3 FROHNER MINE SITE PRELIMINARY EVALUATION AND SCREENING OF ALTERNATIVES

The alternatives identified in Table 7-3 are described, developed, and then subjected to a preliminary evaluation and screening in this section. The evaluation and screening at this stage is based on the anticipated effectiveness, implementability, and relative costs of the alternatives. The preliminary screening has been conducted to identify those alternatives that are obviously not as cost effective or as implementable as other alternatives that would provide a similar degree of risk reduction, thereby possibly reducing the number of reclamation alternatives requiring detailed evaluation.

The evaluation of effectiveness includes determining the ability of an alternative to process the contaminated media sufficiently to achieve the reclamation goals. The reclamation goals include overall protection of human health and the environment, compliance with ARARs, and short- and long-term effectiveness and/or performance related to reducing toxicity, mobility, and/or volume of contaminants. The effectiveness screening criteria included consideration of the nature and extent of the contamination, as well as site-specific conditions, such as geology, hydrology, hydrogeology, climate, current land use, and potential future land use.

The implementability of each alternative has been evaluated to consider the technical and administrative feasibility of constructing, operating, and maintaining each reclamation alternative. Technical feasibility considerations included applicability of the alternative to the waste source(s), availability of the required equipment and expertise to execute the alternative, and overall reliability of the alternative. Administrative feasibility considerations included logistical and scheduling constraints. The evaluation of implementability also considered appropriate combinations of alternatives with respect to site-specific conditions.

Cost screening consists of developing conservative, order-of-magnitude cost estimates for each remedial alternative based on similar sets of assumptions. Costs have been developed by analyzing data available from screening and implementing remedial alternatives at similar sites, particularly past abandoned mine reclamation activities conducted by DEQ/MWCB. Unit and total costs presented in the cost evaluations are present-worth values structured to account for contaminated materials handling, adverse site conditions, and contingency. Total costs were derived by applying estimated unit costs to estimated volumes of contaminated solid media. Cost estimates are based on the following volumes of waste materials:

- approximately 500 cy of tailings material (TP1) covering approximately 0.61 acre;
- approximately 1,000 cy of SSTs covering approximately 0.62 acre;
- approximately 8,900 cy of waste rock covering approximately 2.0 disturbed acres; and
- 6,660 cy of these wastes (WR1, WR3, WR7, and TP1) exceeded the TCLP standards for Pb (refer to Section 3.0). These wastes may require special handling or disposal.

Overall, approximately 3.23 acres at the site have been disturbed by mine wastes, and a total of approximately 10,400 cy of contaminated solid media are present. These estimated volumes are based on volume estimates performed for this EEE/CA.

Most of the adits and shafts accessing the underground workings appear to have been sealed off due to caving or have been barricaded such that access is controlled, with the exception of one open shaft located along the main access road between WR4 and WR6 on USFS property. In addition, the dilapidated existing mill structure is in poor structural condition and may pose as a safety concern.

A screening summary is presented after evaluating each alternative to identify alternatives retained for detailed evaluation in Section 8.0 and to offer rationale for those alternatives that will not be considered further.

7.3.1 Frohner Mine Site Solid Media Alternatives

7.3.1.1 Alternative 1 (Solid Media): No Action

The no action alternative means that no actual reclamation activities would occur at the site to control contaminant migration or to reduce toxicity or volume.

Effectiveness - Protection of human health and the environment would not be achieved under the no action alternative. Prevention of direct human contact would also not be achieved. The solid media contaminant sources present at the Frohner Mine Site contribute significantly to surface water contamination, which presents long-term risks to important environmental resources as well as potential human health risks. No action continues to provide a pathway to affect human health through the food-chain due to uptake of contaminants by fish, other aquatic life, and streamside vegetation. Toxicity, mobility, and volume of contaminants would not be reduced under the no action alternative.

Implementability - Technical and administrative feasibility evaluation criteria do not apply to this alternative.

Cost Screening - No capital or operating costs would be incurred under this alternative.

Screening Summary - This alternative has been retained for further evaluation as suggested by the NCP.

7.3.1.2 Alternative 2 (Solid Media): Institutional Controls

The institutional control alternative includes erecting fences to restrict access to contaminated sources and land use restrictions to prevent land development on or near the affected areas.

Effectiveness - This alternative is not protective of important environmental resources. It is not fully protective of human health if implemented as a stand alone alternative due to allowing the waste sources to continue to contribute significantly to surface and groundwater water contamination. Toxicity, mobility, and volume of the contaminated media would not be reduced under this alternative.

<u>Implementability</u> - Institutional controls are easily implementable based on the criteria of applicability, availability, and reliability. This alternative is considered applicable for minimizing the potential for direct contact and restricting future inappropriate land development. Fencing materials and construction contractors are readily available should direct contact with the area become a problem. Reliability of this alternative for its intended purpose (protection from direct contact) is considered good as long as enforcement of the institutional controls is maintained by the regulatory agencies and landowners. Due to the logistical simplicity of implementing institutional controls, administrative feasibility is considered very good.

<u>Cost Screening</u> - Costs associated with institutional controls would be relatively low as compared to other reclamation measures; however, a considerable amount of fencing materials would be required to fully enclose the contaminated sources present at the site. Capital costs associated with constructing an 8-foot high, chain-link fence would be approximately $105,000 assuming no consolidation of contaminated materials, and a fencing requirement of approximately 5,243 linear feet (excluding SSTs) at approximately $20 per linear foot. Maintenance costs would likely be less than $1,000 per year.

<u>Screening Summary</u> - Institutional controls will not be considered further as a stand-alone reclamation alternative, but may be used in conjunction with other selected treatment alternatives.

7.3.1.3 <u>Alternative 3 (Solid Media): Partial In-Place Containment of Wastes (WR1, WR2, WR5, and WR6) and Partial Waste Consolidation (WR3, WR4, WR7, TP1, and SSTs)</u>

Alternative 3 involves partial in-place containment of waste sources WR1, WR2, WR5, and WR6 (those away from surface water) and partial consolidation of waste sources WR3, WR4, WR7, TP1 and SSTs (those adjacent to surface water). The consolidation area will consist of two possible designs. Alternative 3a consists of placing a one foot coversoil cap on the surface of the completed waste consolidation area. Alternative 3b consists of placing a liner and coversoil cap on the surface of the completed waste consolidation area.

In-place containment would consist of grading the waste sources (WR1, WR2, WR5, and WR6) in-place, liming the surficial 12 inches of the graded waste, placing 12 inches of clean coversoil, and revegetating (Figure 7-1). The purpose of establishing vegetation is to stabilize the surface (provide erosion protection) and to decrease net infiltration through the waste by increasing evapotranspiration.

Containment technologies can involve establishing vegetation directly on the waste source or applying a cover over the waste source upon which the vegetation is established. Covers may range from a simple, single-layered soil cover to complex multi-layered covers consisting of various composite materials. Given the available physical and chemical data/characteristics of the waste sources present at the Frohner Mine Site (the lime requirements for direct vegetation of the waste rock dumps vary from 26.7 to 122.6 tons of lime per acre based on a 12-inch depth of incorporation) it is not reasonable to expect that vegetation could be successfully established on the waste rock dumps by incorporating amendments into the material before seeding, and the waste rock dumps will require a soil cover (Figure 7-1). In addition, because the wastes at the site have few fines, the soil texture of the wastes may not be a suitable growth medium and soil cover would probably be required. Soil covers are often subject to severe surface water erosion problems when placed on overly steep slopes (>3:1 slope). Compaction may help reduce erosion problems; however, excessive compaction is not desirable for successful seed germination.

The waste source material to be disposed of in the constructed consolidation area would include WR7, TP1, and the SSTs. This consolidation area would be located in the immediate vicinity of WR3 and WR4. The consolidation area would cover approximately 0.74 acre and would contain approximately 9,810 cy of wastes.

Conceptual Design and Assumptions

Given the above considerations, the conceptual design for Alternatives 3a involves recontouring some of the waste rock dumps in-place, placing a 12-inch cover soil cap over the recontoured dumps, amending the recontoured dumps as required and revegetating (Figure 7-1); it also includes excavating and consolidating some of the waste sources to a central location away from surface water impacts, placing a 12-inch cover soil cap on the surface of the consolidation area, amending the cover soil as required and revegetating (Figure 7-1). Alternative 3b involves recontouring the same waste rock dumps in-place similar to Alternative 3a (Figure 7-1) and excavating and consolidating some of the waste sources to a central location away from surface water impacts, placing a lined, 24-inch cover soil cap on the surface of the consolidation area, amending the cover soil as required and revegetating (Figure 7-2).

Based on the available data and the above considerations, the conceptual designs of Alternative 3a and 3b include:

- improving road access to the site to facilitate reasonable access by heavy equipment and construction crews;

- improving existing and constructing new surface water diversion ditches to route mine water discharge, run-off/run-on, and seeps away from contaminated solid media, and implementing construction Best Management Practices (BMPs) to protect surface water resources during road construction and reclamation;

- disposing demolition debris located at the site;

- grading solid media (WR1, WR2, WR5, and WR6) in-place to reduce slopes in order to provide surfaces amenable to amendment application or cover soil placement, and revegetation;

- grading solid media (WR3 and WR4) to prepare the consolidation area to receive waste;

- excavating and consolidating WR7, TP1, and the SSTs;
- excavating one-foot of contaminated underlying material from the excavated footprint of WR7, and TP1;
- backfilling excavated areas with cover soil;
- constructing a 12-inch cover soil cap on the surface of the waste consolidation area (Alternative 3a) or constructing a multi-layered cap of the surface of the waste consolidation area (Alternative 3b);
- stream channel reconstruction/channel armoring adjacent to Frohner Meadows Creek may be necessary following removal of WR7, TP1, and SSTs;
- closing the open shaft with a steel grate; and
- revegetating and mulching all disturbed areas upon completion of the construction activities (temporary roads, staging areas, cover soil application areas, etc.).

The current main access road to Frohner Meadows is in generally good condition, but will require minor improvements to allow unobstructed access for the required heavy equipment and machinery. The access road from Frohner Meadows to the site (approximately 1.75 miles) is in fair to poor condition and will likely require widening and grading to allow unobstructed, safe access for the required heavy equipment and machinery. Roads spurs would also be constructed in the vicinity of the waste sources at the site to allow the required heavy equipment to access, excavate and/or grade the wastes.

Run-on/run-off and groundwater control would be achieved by the design and construction of several structures. Temporary surface water diversions would be constructed and BMPs would be implemented to prevent additional sedimentation in Frohner Meadows Creek from occurring during construction. Groundwater discharges from Adit 1 and Adit 2 would be diverted using interceptor ditches to direct water away from downgradient contaminated media, construction areas, and reclaimed areas. Diversion channels would be constructed to divert run-off generated upgradient from each source around the reclaimed areas.

Because the waste materials are coarse and may not be suitable growth media, all regraded waste sources will be covered with 12 inches of cover soil. The regraded surface should be sampled to determine lime requirements after regrading is completed. For planning purposes it has been assumed that the upper 12 inches of all of the regraded dumps will require lime amendment to stabilize metals in the lower root zone.

WR7, TP1, and the SSTs below the Frohner mill are located across the Frohner Meadows Creek floodplain, and Frohner Meadows Creek currently flows through the waste. These waste sources would be removed and consolidated near WR3 in order to provide an unobstructed pathway for Frohner Meadows Creek and minimize impacts to Frohner Meadows Creek.

WR1, WR2, WR5, and WR6 would be graded to a maximum 3H:1V slope (if possible) to minimize potential for erosion and to allow cover soil placement, lime and amendments would be incorporated, and seeding would be accomplished with conventional equipment. Lime would be applied to the waste rock dumps using conventional agricultural techniques (plowing) or deep-incorporation techniques as appropriate.

Because of the steep slopes at the site, WR5 may not be graded to a 3H:1V slope. This dump would require erosion control mat on the surface of the regraded area. Contour furrows, brush mats, and straw rolls could also be used to reduce erosion on the dump face.

For Alternative 3a, the cap for the waste consolidation area would be constructed by amending the surface of the waste to a depth of 12 inches with lime, placing 12 inches of clean cover soil to provide a 2-foot thick layer for establishing vegetation, followed by revegetation of the consolidation area (Figure 7-1). Alternative 3b consists of constructing a multi-layer cap consisting of a textured linear 60-mil low density polyethylene (LLDPE) geomembrane liner, cushion (½-inch minus drainage material) and a 2-foot thick cover soil cap (Figure 7-2).

Seeding would likely take place during the fall of the year. The seed mixture and fertilizer would be applied simultaneously to the prepared seed beds via drill application. Mulch would be applied to promote temporary protection of the disturbed erodible surfaces. Wheat or barley straw mulch (certified weed-free) would be applied over the reclaimed materials with a tow spreader or pneumatic spreader utilizing tucking/crimping as the anchoring mechanism. The steeper slopes of WR5 would be hydroseeded prior to installation of the erosion control mat.

Removal of wastes from near the creek will alter the current channel morphology and stream channel reconstruction or armoring will be needed. Areas where wastes are removed will be armored to stabilize the channel and prevent the creek from cutting into the reclaimed areas.

Physical hazards (high walls, adits/portals, and shafts) would be mitigated as a portion of the reclamation, as described previously.

Effectiveness - The primary purpose of establishing vegetation on a waste source is to limit the contaminant's mobility. Vegetation effectively stabilizes the surface against wind and surface water erosion, and minimizes the potential for migration of vadose zone contaminants from water infiltration by increasing evapotranspiration and decreasing infiltration. Cover soil and vegetation would help minimize human and terrestrial biota exposure to the contaminants via direct contact and inhalation of entrained dust; however, the toxicity or volume of the wastes would not be reduced since no actual treatment of the contaminants would be conducted. Complete removal and consolidation of the waste sources located within the Frohner Meadows Creek floodplain would significantly decrease contaminant mobility at the site. The overall effectiveness of the containment/ revegetation program would be enhanced by carefully selecting appropriate plant species that are metal tolerant and adapted to relatively high altitudes and relatively short growing seasons.

Implementability - These alternatives are both technically and administratively feasible. Incorporation of amendments, soil covers, and establishing vegetation are readily implementable technologies that use conventional construction techniques. However, because of the steep slopes at the site, regrading of the upper dumps may be difficult to implement. Design methods and requirements have been thoroughly tested, and the necessary construction equipment and methods are readily available and widely used. Construction methods may vary depending on the complexity of the terrain and the required depth of amendment incorporation.

Cost Screening - The total present worth cost for Alternative 3a has been estimated at $305,288 and Alternative 3b has been estimated at $400,856, which represents the reclamation of all solid media contaminant sources present at the Frohner Mine Site (tailings and waste rock dumps). Table C-1 (Appendix C) presents the cost details associated with implementing Alternative 3a and Table C-2 (Appendix C) presents the cost details associated with implementing Alternative 3b.

The following assumptions were used to develop costs directly and to calculate associated costs for these alternatives:

- The cost of road access improvements to the site is approximately $2,500 per mile for 1.75 miles.
- To grade waste sources WR1, WR2, WR5, and WR6 to reduce slopes can be completed for an estimated $10,000 per acre.
- The total cost for materials and construction of the temporary surface water diversion structure used to divert the creek is assumed to be $10,000.
- To grade WR3 and WR4 to prepare the consolidation area to receive waste is estimated at $10,000 per acre.
- To excavate and consolidate WR7, TP1, and the SSTs is estimated at $5 per cy (approximately 8,200 cy).
- Approximately 465 feet of reconstructed/stabilized drainage channel will be required in the floodplain adjacent to WR7, TP1, and SSTs at a cost of $35 per foot.
- One foot of cover soil would be used to cover the recontoured waste piles (approximately 1,160 cy). The recontoured surface area of the regraded waste rock dumps is approximately 0.74 acres. Because a suitable cover soil borrow source has not yet been identified at the site, the cover soil would be imported from offsite at an estimated $14 per cy delivered to the site.
- Lime may be required at a 1 foot depth on the graded waste rock dumps at approximately 26.7 to 122.6 tons of lime per acre (based on a 12-inch depth of incorporation). This task can be completed for an estimated $125 per ton.

- One foot of cover soil would be applied to cover the waste consolidation area for Alternative 3a. For Alternative 3b a textured linear 60-mil low density polyethylene (LLDPE) geomembrane liner, cushion (½-inch minus drainage material) and a 2-foot cover soil cap would be placed on the 0.74 acre consolidation area (Figure 7-2).

- The total surface area at the site requiring revegetation and mulching is approximately 3.5 acres (excluding contractor access road spurs, staging areas, etc).

- The total length of required run-on control and adit discharge diversion ditches is 1,500 and 450 linear feet, respectively, at $20 per foot.

- The total cost for removal and disposal of existing debris is estimated at $5,000.

Screening Summary - Partial in-place containment and waste consolidation may be a feasible and cost-effective remedy for the site, and these alternatives have been retained for detailed analysis.

7.3.1.4 Alternative 4 (Solid Media): Complete Removal/Disposal of Solid Media On-Site in an On-Site Modified RCRA Repository

Alternative 4 consists of excavating and disposing of all waste sources at the Frohner Mine Site in a repository. The potential repository location is approximately 0.5 mile to the southwest of the mine site (Figure 7-3). The constructed repository will consist of two possible designs. The first design (Alternative 4a) includes a bottom liner and leachate collection system with a multi-layered lined cap over the waste materials, while the second design (Alternative 4b) would entail a multi-layered cap and liner with no bottom liner. Figures 7-4 and 7-5 illustrate the conceptual cross-sections showing cap features for Alternatives 4a and 4b, respectively.

The waste source material to be disposed of in the constructed repository would include all waste rock (8,900 cy) and tailings material (1,500 cy) at the Frohner Mine Site. The repository would cover approximately 1.0 acre and would contain approximately 15,600 cy of wastes.

Conceptual Design and Assumptions

For the purpose of this evaluation, the conceptual design for Alternative 4a includes removing WR1, WR2, WR3, WR4, WR5, WR6, WR7, TP1, and the SSTs from their current locations and disposing the wastes in a repository consisting of a bottom liner and leachate collection system with a multi-layered lined cap over the waste materials. The conceptual design for Alternative 4b includes removing WR1, WR2, WR3, WR4, WR5, WR6, WR7, TP1, and the SSTs from their current locations and disposing the wastes in a repository without a bottom liner, but with a multi-layered cap over the waste materials.

Based on the available data and the above considerations, the conceptual design of the alternatives include:

- improving road access to the site to facilitate reasonable access by heavy equipment and construction crews;

- constructing temporary surface water diversion structures and implementing construction BMPs to isolate the stream and mine water discharges while excavating wastes from the floodplain and stream channel;

- razing and disposing of any remaining dilapidated buildings/structures remaining at the site;

- installing a geosynthetic clay liner (GCL) bottom liner and leachate collection system similar to that shown on Figure 7-4 (Alternative 4a);

- totally excavating WR1, WR2, WR3, WR4, WR5, WR6, WR7, TP1, and the SSTs from their present locations, and transporting, consolidating, and compacting these contaminated materials in the repository area;

- excavating approximately one foot of contaminated underlying soils from all waste sources, and transporting, consolidating, and compacting the contaminated materials in the repository;

- constructing a multi-layered cap over the waste source material in the repository (Figures 7-4 and 7-5, Alternatives 4a and 4b, respectively);

- importing cover soil to apply to the excavated areas;

- revegetating disturbed areas including the repository cap and areas from which wastes have been removed;

- stream channel reconstruction/stabilization near WR7, TP1, and the SSTs to ensure that the stream channel is stable after waste removal and reclamation have been completed;

- closing the open shaft with a steel grate; and

- constructing surface water diversion ditches/structures throughout the site to route run-off away from the reclaimed source areas.

The current main access road to Frohner Meadows is in generally good condition, but will require minor improvements to allow unobstructed access for the required heavy equipment and machinery. The access road from Frohner Meadows to the site (approximately 1.75 miles) is in fair to poor condition and will likely require widening and grading to allow unobstructed, safe access for the required heavy equipment and machinery. Roads spurs would also be constructed in the vicinity of the waste sources at the site to allow the required heavy equipment to access, excavate and/or grade the wastes.

Run-on/run-off and groundwater control (adit discharges) would be achieved by the design and construction of several structures. Temporary surface water diversions would be constructed and

BMPs would be implemented to prevent additional sedimentation in Frohner Meadows Creek from occurring while excavating waste materials and constructing the repository. Groundwater discharges Adit 1 and Adit 2 would be diverted using interceptor ditches to direct water away from contaminated media, construction areas, and reclaimed areas. Diversion channels would be constructed to divert run-off generated upgradient from each source around the reclaimed areas and into appropriate natural drainages.

Under this alternative, WR1, WR2, WR3, WR4, WR5, WR6, WR7, TP1, and the SSTs and approximately 1 foot of contaminated underlying soils from the waste sources would be removed and moved to the repository located approximately 0.5 mile from the Frohner Mine Site. The excavated areas would be backfilled with clean cover soil and organic amendment and fertilizer to enhance revegetation success.

The area selected for the repository (Figure 7-3) comprises roughly 8.0 acres that appears to be conducive to the construction of a repository, although a repository investigation has not yet been completed. For Alternative 4a, the repository would consist of a composite, multi-layered, cap overlying the waste and a bottom liner/leachate collection system as shown on Figure 7-4. For Alternative 4b, the repository would consist of a composite, multi-layered, cap overlying the waste without a bottom liner system as shown in Figure 7-5. Run-on/run-off control would be constructed as an integral part of the repository design.

The repository will contain approximately 15,600 bank cy of tailings and waste rock. The wastes present at the site are generally unconsolidated and some volume reduction may be achieved when the materials are compacted in the repository. Because of the possible need for over-excavation of waste sources, it is assumed that the capacity of the repository must be at least 15,600 cy.

After the waste sources are excavated and loaded out, the excavated areas would be graded, backfilled with coversoil and revegetated. The areas would be graded to reduce slopes to the extent practical, to eliminate depressions (to promote positive drainage) and to allow placement and incorporation of coversoil and proper soil amendments (if required).

Wherever possible, all slopes to be revegetated would be graded to a maximum 3H:1V slope to minimize potential for erosion and to allow cover soil placement, amendments, and seeding to be accomplished with conventional equipment.

Seeding would likely take place during the fall of the year. The seed mixture and fertilizer would be applied simultaneously to the prepared seed beds via drill application. Mulch would be applied to promote temporary protection of the disturbed erodible surfaces. Wheat or barley straw mulch (certified weed-free) would be applied over the reclaimed materials with a tow spreader or pneumatic spreader utilizing tucking/crimping as the anchoring mechanism.

Physical hazards (high walls, adits/portals, and shafts) would be mitigated as a portion of the reclamation as described previously.

Effectiveness - Both alternatives would effectively reduce contaminant mobility at the site by removing the solid media contaminant sources and disposing of the waste in a secure engineered disposal facility. Consequently, the direct contact and surface water erosion problems associated with the site would be mitigated. Contaminant toxicity and volume would not be reduced; however, the waste's mobility would be substantially reduced in a repository; infiltration of precipitation through the waste sources and resulting migration of contaminants through the vadose zone and groundwater would be significantly reduced. Long-term monitoring and control programs would be established to ensure continued effectiveness.

These alternatives are not expected to provide as high a degree of effectiveness as provided by a repository, which complies with all RCRA Subtitle C regulations; however, they should provide adequate protection at a significantly reduced cost. The design is expected to provide adequate environmental protection considering the chemical and physical characteristics of the mine waste in conjunction with the physical location of the repository site and the area's generally semi arid climate.

Implementability – Both of these alternatives may be technically and administratively feasible. The construction steps required are considered standard/conventional construction practices. Key project components, such as the availability of equipment, materials, and construction expertise, are all present and would help ensure the timely implementation and successful execution of the proposed plan.

Cost Screening - The total present-worth cost for Alternative 4a has been estimated at $681,506, which represents the remediation of all solid media contaminant sources present at the Frohner Mine Site (tailings and waste rock). The cost details associated with implementing this alternative are included in Table C-3 (Appendix C). The total present-worth cost for Alternative 4b has been estimated at $561,310, which represents the remediation of all solid media contaminant sources present at the Frohner Mine Site (tailings and waste rock). The cost details associated with implementing this alternative are included in Table C-4 (Appendix C).

The following assumptions were used to develop costs directly and to calculate associated costs for these alternatives:

- The cost of road access improvements to the site is approximately $2,500 per mile for 1.75 miles.

- The total cost for materials and construction of the temporary surface waste diversion is estimated at $10,000.

- The cost of reconstructing or stabilizing Frohner Meadows Creek in areas where the channel morphology is affected due to waste removal (465 lineal feet) can be completed for $35 per foot.

- The initial excavation for constructing the repository would be approximately 16,133 cy (bank) (Alternative 4a).

- The total volume of waste material to be excavated and hauled to the repository is approximately 15,600 cy, estimated at $5.00 per cy.

- The bottom liner would consist of a finished graded smooth surface overlain by a leachate collection system, GCL liner, and geotextile filter fabric (Alternative 4a) (Figure 7-5).

- Leachate Collection/Removal Layer--A one foot thick layer of washed, coarse gravel would overlay the bottom liner. PVC drain pipes would be installed in conjunction with the coarse gravel layer for leachate collection/removal. A geotextile filter fabric layer (to prevent potential clogging of the coarse gravel) would overlay the primary coarse gravel layer (Alternative 4a).

Note: To increase space for waste disposal (and possibly reduce construction costs), synthetic drainage layers (geonets) can be used in lieu of granular drainage layers in the constructing the repository.

- The repository cap would consist of a multi-layered cap over the waste source material including GCL, geo-cushion, geotextile, and 24-inch thick layer of cover soil (Alternatives 4a and 4b) over the mine wastes.

- The total surface area at the site requiring revegetation and mulching is approximately 4.25 acres (which includes the excavated source areas, and the repository cap) at $1,000 per acre.

- The total volume of clean soils to be imported as cover soils to be placed on the repository is approximately 3,250 cy and the total volume of clean coversoil to be placed at the excavation areas is approximately 5,250 cy at $2.00 per cy and $5.00 per cy, respectively.

- The total length of required run-on control and adit discharge diversion ditches is 2,300 and 450 linear feet, respectively.

Screening Summary - These alternatives have been retained for detailed analysis due to their potential to cost effectively meet reclamation goals for solid media with a proven and relatively uncomplicated technology.

7.3.1.5 Alternative 5a and b (Solid Media): Partial Removal/Disposal of Solid Media On-Site in a Constructed Modified RCRA Repository (WR7, TP1, and SSTs) and Partial In-Place Containment (WR1 through WR6)

Alternative 5 consists of in-place containment of some of the waste sources (WR1 through WR6) present at the site, as well as completely removing all wastes which are located near Frohner Meadows Creek (WR7, TP1, and SSTs) and moving them to the repository identified in Alternative 4.

As with Alternative 4, this alternative will consist of two possible repository designs. Alternative 5a includes a bottom liner and leachate collection system with a multi-layered cap over the waste materials, while the second design (Alternative 5b) would entail a multi-layered cap with no bottom liner. Figures 7-4 and 7-5 illustrate the conceptual cross-sections showing cap features for Alternatives 5a and 5b, respectively.

Conceptual Design and Assumptions

For the purpose of this evaluation, the conceptual design for Alternative 5 includes removing WR7, TP1, and SSTs, consolidating these wastes at the proposed repository location, and containing the waste materials by contouring, covering with soil, and revegetating. Other waste sources at the site (WR1 through WR6) would be recontoured in-place, amended as necessary, covered with soil and revegetated.

The general construction steps for implementing Alternatives 5a and 5b, as conceptualized, are as follows:

- improving road access to the site to facilitate reasonable access by heavy equipment and construction crews;
- constructing temporary surface water diversion structures and implementing construction BMPs to isolate the stream and mine water discharges while excavating wastes from the floodplain and stream channel;
- grading solid media (WR1 through WR6) to reduce slopes in order to provide surfaces amenable to amendment application or cover soil placement, and revegetation;
- razing and disposing of any remaining dilapidated buildings/structures remaining at the site;
- totally excavating WR7, TP1, and the SSTs from their present locations, and transporting these contaminated materials to the repository;
- installing a GCL bottom liner and leachate collection system similar to that shown on Figure 7-4 (Alternative 5a);
- placing and compacting the excavated wastes in the repository;
- constructing a multi-layered cap over the waste source material in the repository (Figures 7-4 and 7-5) (Alternatives 5a and 5b);
- revegetating disturbed areas including the repository cap and areas from which wastes have been removed or graded in-place;
- stream channel reconstruction/stabilization near WR7, TP1, and the SSTs to ensure that the stream channel is stable after waste removal and reclamation have been completed;

- closing the open shaft with a steel grate; and

- constructing surface water diversion ditches/structures throughout the site to route run-off away from the reclaimed source areas.

The current main access road to Frohner Meadows is in generally good condition, but will require minor improvements to allow unobstructed access for the required heavy equipment and machinery. The access road from Frohner Meadows to the site (approximately 1.75 miles) is in fair to poor condition and will likely require widening and grading to allow unobstructed, safe access for the required heavy equipment and machinery. Roads spurs would also be constructed in the vicinity of the waste sources at the site to allow the required heavy equipment to access, excavate and/or grade the wastes.

Run-on/run-off and groundwater control (adit discharges) would be achieved by the design and construction of several structures. Temporary surface water diversions would be constructed and BMPs would be implemented to prevent additional sedimentation in Frohner Meadows Creek from occurring while excavating waste materials and constructing the repository. Groundwater discharges Adit 1 and Adit 2 would be diverted using interceptor ditches to direct water away from contaminated media, construction areas, and reclaimed areas. Diversion channels would be constructed to divert run-off generated upgradient from each source around the reclaimed areas and into appropriate natural drainages.

For both Alternatives 5a and 5b, WR1, WR2, WR3, WR4, WR5, and WR6 would be reclaimed in-place and WR7, TP1, and the SSTs would be removed and moved to the repository located approximately 0.5 mile from the Frohner Mine Site. The recontoured waste sources and the excavated areas would be capped or backfilled with clean cover soil and organic amendment and fertilizer to enhance revegetation success.

In-place containment would consist of grading the waste sources (WR1, WR2, WR3, WR4, WR5, and WR6) in-place, liming the surficial 12 inches of the graded waste, placing 12 inches of clean coversoil, and revegetating (Figure 7-1). The purpose of establishing vegetation is to stabilize the surface (provide erosion protection) and to decrease net infiltration through the waste by increasing evapotranspiration.

The area selected for the repository comprises roughly 8.0 acres that appears to be conducive to the construction of a repository although a repository investigation has not yet been completed. For Alternative 5a, the repository would consist of a composite, multi-layered, cap overlying the waste and a bottom liner/leachate collection system as shown on Figure 7-4. For Alternative 5b, the repository would consist of a composite, multi-layered, cap overlying the waste and without a bottom liner system as shown in Figure 7-5. Run-on/run-off control would be constructed as an integral part of the repository design.

The repository will contain approximately 8,200 cy of tailings and waste rock. The wastes present at the site are generally unconsolidated and some volume reduction may be achieved when the materials are compacted in the repository. However, because of the possible need for over-excavation of waste sources, it is assumed that the capacity of the repository must be at least 8,200 cy.

After the waste sources are excavated and loaded out, the excavated areas would be graded, backfilled with coversoil and revegetated. The areas would be graded to reduce slopes to the extent practical, to eliminate depressions (to promote positive drainage) and to allow placement and incorporation of coversoil and proper soil amendments (if required).

Wherever possible, all slopes to be revegetated would be graded to a maximum 3H:1V slope to minimize potential for erosion and to allow cover soil placement, amendments, and seeding to be accomplished with conventional equipment.

Seeding would likely take place during the fall of the year. The seed mixture and fertilizer would be applied simultaneously to the prepared seedbeds via drill application. Mulch would be applied to promote temporary protection of the disturbed erodible surfaces. Wheat or barley straw mulch (certified weed-free) would be applied over the reclaimed materials with a tow spreader or pneumatic spreader utilizing tucking/crimping as the anchoring mechanism.

Physical hazards (high walls, adits/portals, and shafts) would be mitigated as a portion of the reclamation as described previously.

Effectiveness – Both Alternatives 5a and 5b would effectively reduce contaminant mobility at the Frohner Mine Site by removing the highest risk solid media contaminant sources and disposing of the waste in a secure disposal facility away from the site and would eliminate solid media risks at the site. Consequently, the direct contact and surface water erosion problems associated with the site would be mitigated.

Contaminant toxicity and volume would not be reduced; however, the waste's mobility would be substantially reduced in a lined repository; infiltration of precipitation through the waste sources and resulting migration of contaminants through the vadose zone and groundwater would also be significantly reduced. Long-term monitoring and control programs would be established to ensure continued effectiveness.

These alternatives are not expected to provide as high a degree of effectiveness as provided by a repository, which complies with all RCRA Subtitle C regulations; however, they should provide adequate protection at a significantly reduced cost. This design is expected to provide adequate environmental protection considering the chemical and physical characteristics of the mine waste in conjunction with the physical location of the repository site and the area's generally arid climate.

Implementability - These alternatives should be technically and administratively feasible. The construction steps required are considered standard/conventional construction practices. Key project components, such as the availability of equipment, materials, and construction expertise, are all present and would help ensure the timely implementation and successful execution of the proposed plan.

<u>Cost Screening</u> - The total present-worth cost for Alternative 5a has been estimated at $489,019, which represents partial in-place containment of wastes not located near surface water and removal of wastes located near a surface water feature to a repository consisting of a bottom liner and multi-layer cap. The cost details associated with implementing this alternative are included in Table C-5 (Appendix C). The total present-worth cost for Alternative 4b has been estimated at $439,427, which represents partial in-place containment of wastes not located near surface water and removal of wastes located near a surface water feature to a repository consisting of a multi-layer cap. The cost details associated with implementing this alternative are included in Table C-6 (Appendix C).

The following assumptions were used to develop costs directly and to calculate associated costs for these alternatives:

- The cost of road access improvements to the site is approximately $2,500 per mile for 1.75 miles.

- To grade waste sources WR1 through WR6 to reduce slopes can be completed for an estimated $10,000 per acre.

- The total cost for materials and construction of a temporary surface water diversion structure used to divert the creek is assumed to be $10,000.

- The total volume of waste material (WR7, TP1, and SSTs) to be excavated and hauled to the repository is approximately 8,200 cy.

- The initial excavation for constructing the repository would be approximately 4,840 cy.

- The bottom liner would consist of a finished graded smooth surface overlain by a GCL liner (Alternative 5a).

- Leachate Collection/Removal Layer--A 1 foot thick layer of washed, coarse gravel would overlay the bottom liner. PVC drainpipes would be installed in conjunction with the coarse gravel layer for leachate collection/removal. A geotextile filter fabric layer (to prevent potential clogging of the coarse gravel) would overlay the primary coarse gravel layer (Alternative 5a).

- The cost of reconstructing or stabilizing Frohner Meadows Creek in areas where the channel morphology is affected due to waste removal (465 lineal feet) can be completed for $35 per foot.

Note: To increase space for waste disposal (and possibly reduce construction costs), synthetic drainage layers (geonets) can be used in lieu of granular drainage layers in the constructing the repository.

- The repository cap would consist of a multi-layered cap over the waste source material including GCL, geo-cushion, geotextile, and 24-inch thick layer of cover soil (Alternatives 5a and 5b) over the mine wastes.

- The total surface area at the site requiring revegetation is approximately 3.5 acres (which includes the excavated source areas, and the repository cap).

- The total volume of clean soils to be placed on the repository is approximately 970 cy (Alternatives 5a and 5b). The total volume of clean soils to be placed on the reclaimed in-place waste sources is approximately 2,100 cy.

- Lime may be required at a 1 foot depth on the graded waste rock dumps at approximately 26.7 to 122.6 tons of lime per acre (based on a 12-inch depth of incorporation). This task can be completed for an estimated $125 per ton.

- The total length of required run-on control and adit discharge diversion ditches is 2,300 and 450 linear feet, respectively.

Screening Summary - These alternatives have been retained for detailed analysis as means of comparison to other alternatives.

7.3.1.6 Alternative 5c (Solid Media): Partial Removal/Disposal of Solid Media On-Site in a Constructed Modified RCRA Repository (WR7, WR3, TP1, and SSTs) and Partial In-Place Containment (WR1, WR2, WR4, WR5, and WR6)

Alternative 5c consists of in-place containment of some of the waste sources (WR1, WR2, WR4, WR5, and WR6) present at the site, as well as completely removing all wastes which fail TCLP analyses (WR3, WR7, TP1, and SSTs) and moving them to the repository identified in Alternative 4. The repository design for this alternative consists of a multi-layered cap with no bottom liner. Figure 7-5 illustrates the conceptual cross-section showing the cap features.

Conceptual Design and Assumptions

For the purpose of this evaluation, the conceptual design for Alternative 5c includes completely removing WR3, WR7, TP1, and SSTs, consolidating these wastes at the proposed repository location, and containing the waste materials by contouring, covering with soil, and revegetating. Other waste sources at the site (WR1, WR2, WR4, WR5, and WR6) would be recontoured in-place, amended as necessary, covered with soil and revegetated.

The general construction steps for implementing Alternatives 5c, as conceptualized, are as follows:

- improving road access to the site to facilitate reasonable access by heavy equipment and construction crews;

- constructing temporary surface water diversion structures and implementing construction BMPs to isolate the stream and mine water discharges while excavating wastes from the floodplain and stream channel;

- grading solid media (WR1, WR2, WR4, WR5, and WR6) to reduce slopes in order to provide surfaces amenable to amendment application or cover soil placement, and revegetation;

- razing and disposing of any remaining dilapidated buildings/structures remaining at the site;

- completely excavating WR3, WR7, TP1, and the SSTs from their present locations, and transporting these contaminated materials to the repository;

- placing and compacting the excavated wastes in the repository;

- constructing a multi-layered cap over the waste source material in the repository (Figures 7-5);

- revegetating disturbed areas including the repository cap and areas from which wastes have been removed or graded in-place;

- stream channel reconstruction/stabilization near WR7, TP1, and the SSTs to ensure that the stream channel is stable after waste removal and reclamation have been completed;

- closing the open shaft with a steel grate; and

- constructing surface water diversion ditches/structures throughout the site to route run-off away from the reclaimed source areas.

The current main access road to Frohner Meadows is in generally good condition, but will require minor improvements to allow unobstructed access for the required heavy equipment and machinery. The access road from Frohner Meadows to the site (approximately 1.75 miles) is in fair to poor condition and will likely require widening and grading to allow unobstructed, safe access for the required heavy equipment and machinery. Roads spurs would also be constructed in the vicinity of the waste sources at the site to allow the required heavy equipment to access, excavate and/or grade the wastes.

Run-on/run-off and groundwater control (adit discharges) would be achieved by the design and construction of several structures. Temporary surface water diversions would be constructed and BMPs would be implemented to prevent additional sedimentation in Frohner Meadows Creek from occurring while excavating waste materials and constructing the repository. Groundwater discharges Adit 1 and Adit 2 would be diverted using interceptor ditches to direct water away from contaminated media, construction areas, and reclaimed areas. Diversion channels would be constructed to divert run-off generated upgradient from each source around the reclaimed areas and into appropriate natural drainages.

For this alternative, WR1, WR2, WR4, WR5, and WR6 would be reclaimed in-place and WR3, WR7, TP1, and the SSTs would be removed and moved to the repository located approximately 0.5 mile from the Frohner Mine Site. The recontoured waste sources and the excavated areas would be capped or backfilled with clean cover soil and organic amendment and fertilizer to enhance revegetation success.

In-place containment would consist of grading the waste sources (WR1, WR2, WR4, WR5, and WR6) in-place, liming the surficial 12 inches of the graded waste, placing 12 inches of clean coversoil, and revegetating (Figure 7-1). The purpose of establishing vegetation is to stabilize the surface (provide erosion protection) and to decrease net infiltration through the waste by increasing evapotranspiration.

The area selected for the repository comprises roughly 8.0 acres that appears to be conducive to the construction of a repository although a repository investigation has not yet been completed. For Alternative 5c, the repository would consist of a composite, multi-layered, cap overlying the waste and without a bottom liner system as shown in Figure 7-5. Run-on/run-off control would be constructed as an integral part of the repository design.

The repository will contain approximately 10,106 cy of tailings and waste rock. The wastes present at the site are generally unconsolidated and some volume reduction may be achieved when the materials are compacted in the repository. However, because of the possible need for over-excavation of waste sources, it is assumed that the capacity of the repository must be at least 10,106 cy.

After the waste sources are excavated and loaded out, the excavated areas would be graded, backfilled with coversoil and revegetated. The areas would be graded to reduce slopes to the extent practical, to eliminate depressions (to promote positive drainage) and to allow placement and incorporation of coversoil and proper soil amendments (if required).

Wherever possible, all slopes to be revegetated would be graded to a maximum 3H:1V slope to minimize potential for erosion and to allow cover soil placement, amendments, and seeding to be accomplished with conventional equipment.

Seeding would likely take place during the fall of the year. The seed mixture and fertilizer would be applied simultaneously to the prepared seedbeds via drill application. Mulch would be applied to promote temporary protection of the disturbed erodible surfaces. Wheat or barley straw mulch (certified weed-free) would be applied over the reclaimed materials with a tow spreader or pneumatic spreader utilizing tucking/crimping as the anchoring mechanism.

Physical hazards (high walls, adits/portals, and shafts) would be mitigated as a portion of the reclamation as described previously.

Effectiveness – Alternatives 5c would effectively reduce contaminant mobility at the Frohner Mine Site by removing the highest risk solid media contaminant sources and disposing of the waste in a secure disposal facility away from the site and would eliminate solid media risks at the site. Consequently, the direct contact and surface water erosion problems associated with the site would be mitigated.

Contaminant toxicity and volume would not be reduced; however, the waste's mobility would be substantially reduced in a lined repository; infiltration of precipitation through the waste sources and resulting migration of contaminants through the vadose zone and groundwater would also be significantly reduced. Long-term monitoring and control programs would be established to ensure continued effectiveness.

This alternative is not expected to provide as high a degree of effectiveness as provided by a repository, which complies with all RCRA Subtitle C regulations; however, they should provide adequate protection at a significantly reduced cost. This design is expected to provide adequate environmental protection considering the chemical and physical characteristics of the mine waste in conjunction with the physical location of the repository site and the area's generally arid climate.

Implementability - These alternatives should be technically and administratively feasible. The construction steps required are considered standard/conventional construction practices. Key project components, such as the availability of equipment, materials, and construction expertise, are all present and would help ensure the timely implementation and successful execution of the proposed plan.

This alternative's cost can possibly be further reduced and implemented faster by leaving the majority of the waste sources located on USFS property (WR1 and WR4) as is for that agency to address per their guidelines. The amount of risk reduction achieved by containing these waste sources in-place versus no action is minute.

Cost Screening - The total present-worth cost for Alternative 5c has been estimated at $426,334 which represents partial in-place containment of wastes and removal of wastes failing TCLP to a repository consisting of a multi-layer cap. The cost details associated with implementing this alternative are included in Table C-7 (Appendix C).

The following assumptions were used to develop costs directly and to calculate associated costs for these alternatives:

- The cost of road access improvements to the site is approximately $2,500 per mile for 1.75 miles.

- To grade waste sources WR1, WR2, WR4, WR5, and WR6 to reduce slopes can be completed for an estimated $10,000 per acre.

- The total cost for materials and construction of a temporary surface water diversion structure used to divert the creek is assumed to be $10,000.

- The total volume of waste material (WR3, WR7, TP1, and SSTs) to be excavated and hauled to the repository is approximately 10,106 cy.

- The initial excavation for constructing the repository would be approximately 4,840 cy.

- The cost of reconstructing or stabilizing Frohner Meadows Creek in areas where the channel morphology is affected due to waste removal (465 lineal feet) can be completed for $35 per foot.

- The repository cap would consist of a multi-layered cap over the waste source material including GCL, geo-cushion, geotextile, and 24-inch thick layer of cover over the mine wastes.

- The total surface area at the site requiring revegetation is approximately 3.5 acres (which includes the excavated source areas, and the repository cap).

- The total volume of clean soils to be placed on the repository is approximately 970 cy. The total volume of clean soils to be placed on the reclaimed in-place waste sources is approximately 2,100 cy.

- Lime may be required at a 1 foot depth on the graded waste rock dumps at approximately 26.7 to 122.6 tons of lime per acre (based on a 12-inch depth of incorporation). This task can be completed for an estimated $125 per ton.

- The total length of required run-on control and adit discharge diversion ditches is 2,300 and 450 linear feet, respectively.

Screening Summary - These alternatives have been retained for detailed analysis as means of comparison to other alternatives.

7.3.1.7 Alternative 6 (Solid Media): Removal/Disposal of all Waste Material in the Luttrell Pit

Alternative 6 consists of excavating and disposing of all solid waste material from the Frohner Mine Site in an existing mine waste repository located at the Luttrell Pit in Township 8 North, Range 5 West, Section 19 (Figure 7-6). This repository was constructed by the EPA to dispose of waste material excavated from numerous abandoned or inactive mines in its vicinity. The repository is capable of containing approximately 1.5 million cy of mine waste (DEQ/MWCB-Pioneer, 1996).

Solid waste material to be disposed of in the repository would include all waste rock material from the Frohner Mine Site; approximately 10,400 cy. Following removal of the tailings and waste rock dumps, coversoil would be backfilled in the excavation areas, amended if necessary, seeded, and mulched.

The creek channel would be stabilized and/or armored in areas that would be altered due to dump excavation. Because the waste rock and tailings materials are located in or near Frohner Meadows Creek, necessary stream protection measures would be designed as an integral part of the reclamation strategy.

Conceptual Design and Assumptions

Based on the available data and the above considerations, the conceptual design for Alternative 6 includes:

- improving road access to the site to facilitate reasonable access by heavy equipment and construction crews;
- improving existing roads for hauling solid waste material from the Frohner Mine Site to the Luttrell Pit Repository;
- constructing temporary surface water diversion structures and implementing construction BMPs to isolate the stream and mine water discharges while excavating wastes from the floodplain and stream channel.
- razing and disposing of dilapidated buildings/structures remaining at the site;
- excavating the waste sources present at the Frohner Mine and Mill (WR1 through WR7, TP1 and SSTs), transporting, and consolidating contaminated material at the existing Luttrell Pit;
- importing coversoil and applying to the excavated areas (because a suitable cover soil borrow source has not yet been identified at the site, the cover soil would be imported from off-site and delivered to the site);
- stream channel reconstruction/stabilization at excavated areas along Frohner Meadows Creek (WR7, TP1, and SSTs);
- constructing surface water ditches to re-route adit discharges at Adit 1 and Adit 2;
- closing open shaft with a steel grate; and
- revegetating and mulching all disturbed areas upon completion of the construction activities (temporary roads, staging areas, cover soil application areas, etc.).

The current main access road to Frohner Meadows is in generally good condition, but will require minor improvements to allow unobstructed access for the required heavy equipment and machinery. The access road from Frohner Meadows to the site (approximately 1.75 miles) is in fair to poor condition and will likely require widening and grading to allow unobstructed, safe access for the required heavy equipment and machinery. Roads spurs would also be constructed in the vicinity of the waste sources at the site to allow the required heavy equipment to access, excavate and/or grade the wastes.

Access routes to the Luttrell Pit (approximately 12 miles [one-way]) range from poor to moderate conditions. The access road will require improvement for hauling of solid waste material from the Frohner Mine Site to the Luttrell Pit.

Run-on/run-off and groundwater control would be achieved by the design and construction of several structures. Temporary surface water diversions would be constructed and BMPs would be implemented to prevent additional sedimentation in Frohner Meadows Creek from occurring during construction. Groundwater discharges from Adit 1 and Adit 2 would be diverted using interceptor ditches to direct water away from downgradient contaminated media, construction areas, and reclaimed areas. Diversion channels would be constructed to divert run-off generated upgradient from each source around the reclaimed areas.

Lime would not be required for this alternative because all of the waste rock dump material would be removed to Luttrell Pit. Clean backfill materials would be placed on the disturbed footprint areas and where temporary access roads are constructed.

Seeding would likely take place during the fall of the year. The seed mixture and fertilizer would be applied simultaneously to the prepared seed beds via drill application. Mulch would be applied to promote temporary protection of the disturbed erodible surfaces. Wheat or barley straw mulch (certified weed-free) would be applied over the reclaimed materials with a tow spreader or pneumatic spreader utilizing tucking/crimping as the anchoring mechanism.

Effectiveness - This alternative would effectively reduce solid media contaminant mobility at the site by removing the highest risk solid media contaminant sources and disposing of the waste in a secure disposal facility. Consequently, the surface water erosion problems are expected to be corrected. Contaminant toxicity and volume would not be reduced; however, the waste would be rendered immobile in an engineered structure and physical location protected from erosion problems. Long-term monitoring and control programs would be necessary to ensure continued effectiveness.

Implementability - This alternative is both technically and administratively feasible. Design methods and requirements have been thoroughly tested, and the necessary construction equipment and methods are readily available and widely used. Construction methods may vary depending on the complexity of the terrain. Although, a multi-agency agreement between the MDEQ/MWCB, USFS, and EPA would be required prior to disposal of any waste in this facility.

Cost Screening - The total present worth cost for this alternative has been estimated at $644,860. This alternative would achieve reclamation of all waste source material located at Frohner Mine and Mill. Table C-8 (Appendix C) presents the cost details associated with implementing Alternative 6. The total cost does not include O&M for the Luttrell Pit repository, which would be proportional to the total amount of waste contributed to the facility or potential "pre-treatment" requirements necessary prior to disposing of the material at this facility.

The following assumptions were used to develop costs directly and to calculate associated costs for this alternative:

- The cost of upgrading and constructing temporary road access to the Frohner Mine and Mill can be completed for an estimated $2,500 per mile.

- The cost of upgrading the access road from the Frohner Mine and Mill to the Luttrell Pit can be completed for an estimated $1,500 per mile.

- The total cost for materials and construction of the temporary surface water diversion structure used to divert the creek is assumed to be $10,000.

- Approximately 10,400 cy of waste rock material would be removed, transported, and disposed of in the Luttrell Pit for a total estimated cost of $18 per cubic yard.

- Approximately 5,300 cy of clean fill material will be used to cover the waste rock dump footprint areas. Because a suitable borrow source has not been identified at the site, the coversoil would be imported from off-site at an estimated cost of $14 per cubic yard delivered to the site.

- Approximately 465 feet of reconstructed/stabilized drainage channel will be required in the floodplain adjacent to WR7, TP1, and SSTs at a cost of $35 per foot.

- The total surface area at the site requiring revegetation and mulching is approximately 3.25 acres (excluding contractor access road spurs, staging areas, etc).

- The total length of required run-on control and adit discharge diversion ditches is 1,500 and 450 linear feet respectively at $20 per foot.

- The total cost for removal and disposal of existing buildings and debris is estimated at $5,000.

Screening Summary - Alternative 6 has been retained for detailed analysis since complete removal and disposal in the Luttrell Pit repository may be an effective, feasible and cost-effective remedy for the site.

7.3.1.8 Alternative 7: Removal/Treatment/Disposal at a Permitted Off-Site Hazardous Waste Disposal Facility

The remedial strategy for Alternative 7 involves removing the solid media contaminant sources at the Frohner Mine Site, which are the principal sources of concern (those sources which contribute the highest relative risks) and disposing of these wastes in a permitted waste disposal facility. The majority of the waste sources at the site exhibit hazardous waste characteristics as determined by TCLP analysis. The materials could be disposed at a RCRA-permitted hazardous

waste facility or at a municipal solid waste landfill; both possibilities are discussed in the following paragraphs.
Since the materials exhibit hazardous waste characteristics, they may be shipped directly to a RCRA-permitted hazardous waste facility. The two nearest RCRA-permitted hazardous waste disposal facilities with the capacity to dispose of the wastes are both located several hundred miles from the site (one facility is located in Idaho, the other in Oregon). Approximately 10,400 cy (or about 14,560 tons) of waste rock and tailings would be removed from the site and transported to the RCRA facility. Since the materials fail TCLP for Pb (land-banned substances), treatment would be required before disposal. This treatment would most likely consist of solidification/stabilization conducted by the RCRA facility.

Alternatively, the materials could be excavated and treated on-site to remove their hazardous characteristics. The most likely form of treatment would be solidification/stabilization using Portland cement and/or pozzolonic materials. Once the materials have been treated, they could be disposed off-site at a permitted municipal solid waste (Montana Class II) landfill. Treatment and disposal in this manner would be allowable since the materials are excluded from RCRA hazardous waste regulations under the Bevill Amendment. (Even though they are Bevill excluded, the materials must be treated to remove their hazardous characteristics before they would be accepted by a Class II landfill.) Once the hazardous characteristics are removed from the materials through treatment, disposal in a Class II landfill would provide adequate environmental protection, including long-term monitoring and maintenance of the facility as required by solid waste regulations in ARM 16.14.531.

Fees for treatment and disposal (including taxes) at a RCRA hazardous waste facility are estimated at $250 per ton. Hauling costs would be approximately $60 per ton. When stabilization testing, waste profiling, and excavation are considered, the total cost per ton for off-site treatment and disposal at a hazardous waste facility would be approximately $310 per ton. On-site treatment to remove hazardous characteristics, coupled with transportation and disposal at a Class II landfill, is estimated to be approximately $20 per ton. This option would require extensive testing to determine the optimum stabilization mix to remove the hazardous characteristics.

Conceptual Design and Assumptions

For the purpose of this evaluation, the conceptual design for Alternative 7 includes removing WR1, WR2, WR3, WR4, WR5, WR6, WR7, TP1, and the SSTs from their current locations and disposing the wastes at an off-site facility.

Based on the available data and the above considerations, the conceptual design of Alternative 7 includes:

- improving road access to the site to facilitate reasonable access by heavy equipment and construction crews;

- constructing temporary surface water diversion structures and implementing construction BMPs to isolate the stream and mine water discharges while excavating wastes from the floodplain and stream channel;

- razing and disposing of any remaining dilapidated buildings/structures remaining at the site;

- totally excavating WR1, WR2, WR3, WR4, WR5, WR6, WR7, TP1, and the SSTs from their present locations, and transporting these contaminated materials off-site to the disposal facility;

- revegetating disturbed areas including areas from which wastes have been removed;

- stream channel reconstruction to ensure that the stream channel is stable after waste removal and reclamation have been completed;

- backfilling cuts to stabilize highwalls and recontouring the areas to control run-off;

- closing the open shafts with a steel grate; and

- constructing surface water diversion ditches/structures throughout the site to route run-off away from the reclaimed source areas.

The current main access road to Frohner Meadows is in generally good condition, but will require minor improvements to allow unobstructed access for the required heavy equipment and machinery. The access road from Frohner Meadows to the site (approximately 1.75 miles) is in fair to poor condition and will likely require widening and grading to allow unobstructed, safe access for the required heavy equipment and machinery. Roads spurs would also be constructed in the vicinity of the waste sources at the site to allow the required heavy equipment to access, excavate and/or grade the wastes.

Run-on/run-off and groundwater control (adit discharges) would be achieved by the design and construction of several structures. Temporary surface water diversions would be constructed and BMPs would be implemented to prevent additional sedimentation in Frohner Meadows Creek from occurring while excavating waste materials and constructing the repository. Groundwater discharges Adit 1 and Adit 2 would be diverted using interceptor ditches to direct water away from contaminated media, construction areas, and reclaimed areas. Diversion channels would be constructed to divert run-off generated upgradient from each source around the reclaimed areas and into appropriate natural drainages.

Under this alternative WR1, WR2, WR3, WR4, WR5, WR6, WR7, TP1, and the SSTs would be removed and moved hauled off-site to the disposal facility. The underlying native soils would remain in place and would be amended with lime to adjust the pH and to stabilize the metals, if needed. The native soils would be amended with compost and fertilizer to enhance revegetation success. The underlying soils should be sampled to determine lime requirement and agronomic properties prior to amendment, seedbed preparation, and planting.

After the waste sources are excavated and loaded out, the excavated areas would be graded and revegetated. The areas would be graded to reduce slopes to the extent practical, to eliminate depressions (to promote positive drainage) and to allow placement and incorporation of proper soil amendments (if required). The underlying native soils would remain in place and would be amended with lime to adjust the pH and to stabilize the metals, if needed. The native soils would be amended with compost and fertilizer to enhance revegetation success. The underlying soils should be sampled to determine lime requirement and agronomic properties prior to amendment, seedbed preparation and planting.

Wherever possible, all slopes to be revegetated would be graded to a maximum 3H:1V slope to minimize potential for erosion and to allow cover soil placement, incorporation of lime and amendments, and seeding to be accomplished with conventional equipment. Lime would be applied to the waste source footprints using conventional agricultural techniques (plowing) or deep-incorporation techniques as appropriate.

Seeding would likely take place during the fall of the year. The seed mixture and fertilizer would be applied simultaneously to the prepared seed beds via drill application. Mulch would be applied to promote temporary protection of the disturbed erodible surfaces. Wheat or barley straw mulch (certified weed-free) would be applied over the reclaimed materials with a tow spreader or pneumatic spreader utilizing tucking/crimping as the anchoring mechanism.

Reconstruction of the Frohner Meadows Creek channel will be required to establish a stable surface water drainage system.

Physical hazards (high walls, adits/portals, and shafts) would be mitigated as a portion of the reclamation as described previously.

Effectiveness - This alternative would effectively reduce contaminant toxicity through treatment that would be required prior to disposal off-site, and would eliminate solid media risks at the Frohner Mine and Mill Site. Also, the contaminant mobility would be reduced through treatment and placing the wastes in an off-site landfill. Contaminant volume would not be reduced. Disposal at a Class II landfill or a RCRA-permitted hazardous waste facility establishes long-term monitoring and control programs to ensure continued effectiveness. However, short-term risks of exposure to the contaminated material would occur during transport to the disposal facility.

Implementability - This alternative is technically feasible, although some difficulties could be caused by any coarse waste rock materials. The construction steps required (excavation and loadout) are considered standard construction practices. Solidification/stabilization is also a standard, well-proven process to remove hazardous characteristics from solid wastes, although it may not be feasible to crush and grind the waste rock on-site. This alternative is most likely administratively feasible; however, there are some possible limitations; primarily, a Class II landfill must agree to accept the wastes. It is possible that a number of Class II landfills would be required to accommodate the large volume of wastes. Alternatively, a hazardous waste facility must be willing to accept, treat, and dispose the materials; this should not be administratively difficult.

Cost Screening - The total present-worth cost for this alternative has been estimated at $734,510. The cost details associated with implementing this alternative as described are included in Table C-9 (Appendix C).

The following assumptions were used to develop costs directly and to calculate associated costs for this alternative:

- The cost of road access improvements to the site is approximately $2,500 per mile for 1.75 miles.

- The total cost for materials and construction of the temporary surface water diversion structure used to divert the creek is assumed to be $10,000.

- The total volume of waste material to be excavated and hauled off-site is approximately 10,400 cy.

- The cost of reconstructing or stabilizing Frohner Meadows Creek in areas where the channel morphology is affected due to waste removal (465 lineal feet) can be completed for $35 per foot.

- The total surface area at the site requiring revegetation and mulching is approximately 4.5 acres (excluding contractor access road spurs, staging areas, etc).

- The total length of required run-on control and adit discharge diversion ditches is 1,500 and 450 linear feet respectively at $20 per foot.

- The total cost for removal and disposal of existing buildings and debris is estimated at $5,000.

Screening Summary - This alternative has not been retained for detailed analysis because of the high cost and potential difficulties associated with successful treatment of the coarse waste rock fragments.

7.3.2 Contaminated Aqueous Media Alternatives

Alternatives to address contaminated aqueous media at the site were considered in the Reclamation Investigation Work Plan for the Frohner Mine Site (DEQ/MWCB-Pioneer, 1998a) and were eliminated for reason presented in the plan. Because these alternatives were eliminated, no discussion is provided in this report.

7.4 FROHNER MINE AND MILLSITE SUMMARY OF ALTERNATIVE SCREENING

Table 7-4 summarizes the findings of the solid media alternatives preliminary evaluation and screening. Costs generated and summarized on this table are present-worth values.

The aqueous media alternatives are not included in the table, since they have been subjected to a preliminary evaluation, but have been screened from consideration. As explained earlier in this section, the need for additional action to address the contaminated aqueous media will not be clearly defined until a solid media alternative has been selected and implemented.

8.0 DETAILED ANALYSIS OF ALTERNATIVES

The purpose of the detailed analysis is to evaluate, in detail, reclamation alternatives for their effectiveness, implementability, and associated cost to control and reduce the toxicity, mobility, and/or volume of contaminated solid wastes at the Frohner Mine and Millsite. Only those reclamation alternatives which were retained after the preliminary evaluation and screening (as presented in Section 7.0) are included. For clarity, the retained alternative numbers are carried over from Section 7.0. The reclamation alternatives evaluated in detail are applicable to the contaminated solid waste material only. The rationale for not directly developing reclamation alternatives for surface water contamination was based primarily on the presumption that reclaiming the solid waste sources along Frohner Meadows Creek will subsequently reduce the problems associated with surface water at a significantly reduced cost.

As required by the CERCLA and the NCP, reclamation alternatives that were retained after the initial evaluation and screening have been evaluated individually against the following criteria:

1. overall protection of human health and the environment;
2. compliance with ARARs;
3. long-term effectiveness and permanence;
4. reduction of toxicity, mobility, or volume through treatment;
5. short-term effectiveness;
6. implementability; and
7. cost.

Supporting agency acceptance and community acceptance are additional criteria that will be addressed after both the agencies and public have reviewed the evaluations presented herein. The analysis criteria have been used to address the CERCLA requirements and considerations with EPA guidance (EPA, 1988a), as well as additional technical and policy considerations. These criteria serve as the basis for conducting the detailed analysis and subsequently selecting the preferred reclamation alternative. The criteria listed above are categorized into three groups, each with distinct functions in selecting the preferred alternative. These groups include:

- Threshold Criteria - overall protection of human health and the environment and compliance with ARARs.

- Primary Balancing Criteria - long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost.

- Modifying Criteria - supporting agency and community acceptance.

Overall protection of human health and the environment and compliance with applicable or relevant and appropriate requirements are threshold criteria that must be satisfied for an alternative to be eligible for selection. Long-term effectiveness and permanence; reduction of toxicity, mobility, or volume; short-term effectiveness; implementability; and cost are the primary balancing factors used to weigh major trade-offs between alternative hazardous waste management strategies. Supporting agency and community acceptance are modifying considerations that are formally considered after public comment is received on the proposed plan (Federal Register, No. 245, 51394-50509, December 1988). Each criterion is briefly described in the following paragraphs.

The overall protection criterion evaluates how the alternative, as a whole, protects and maintains human health and the environment. The overall assessment of protection is based on a combination of factors assessed under other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

Compliance with ARARs criterion assesses how each alternative complies with applicable or relevant and appropriate standards, criteria, advisories, or other guidelines. Waivers will be identified, if necessary. The following factors will be addressed for each alternative during the detailed analysis of ARARs:

- compliance with chemical-specific ARARs;
- compliance with action-specific ARARs;
- compliance with location-specific ARARs; and
- compliance with appropriate criteria, advisories, and guidelines.

Long-term effectiveness and permanence evaluates the alternative's effectiveness in protecting human health and the environment after response objectives have been met. The following components of the criterion will be addressed for each alternative:

- magnitude of residual risk;
- adequacy of controls; and
- reliability of controls.

The reduction of toxicity, mobility, or volume assessment evaluates anticipated performance of the specific treatment technologies. This evaluation focuses on the following specific factors for a particular reclamation alternative:

- the treatment process, the remedies they will employ, and the materials they will treat;

- the amount of hazardous materials that will be destroyed or treated, including how principal threat(s) will be addressed;

- the degree of expected reduction in toxicity, mobility, or volume measured as a percentage of reduction (or order of magnitude);

- degree to which the treatment will be irreversible; and

- the type and quantity of treatment residuals (i.e., wastewater treatment sludges, spent reagents) that will remain following treatment.

Short-term effectiveness evaluates an alternative's effectiveness in protecting human health and the environment during the construction and implementation period until the response objectives are met. Factors that will be considered under this criterion include:

- protection of the surrounding community during reclamation actions;
- protection of on-site workers during reclamation actions;
- protection from environmental impacts; and
- time until removal response objectives are achieved.

Implementability evaluates the technical and administrative feasibility of alternatives and the availability of required resources. Analysis of this criterion will include the following factors and subfactors:

<u>Technical Feasibility</u>

- construction and operation;
- reliability of technology;
- ease of undertaking additional remedial action; and
- monitoring considerations.

<u>Administrative Feasibility</u>

- RCRA disposal restrictions;
- institutional controls; and
- permitting requirements.

<u>Availability of Services and Materials</u>

- adequate off-site treatment, storage capacity, and disposal service;

- necessary equipment and specialists and provisions to ensure any necessary additional resources;

- timing of the availability of technologies under consideration; and

- services and materials.

The cost assessment consists of developing conservative, order-of-magnitude cost estimates based on similar sets of site-specific assumptions. Cost estimates for each alternative will consider the following factors:

<u>Capital Costs</u>

- construction costs;
- equipment costs;

- land and site development costs;
- disposal costs;
- legal fees, license, and permit costs;
- startup and troubleshooting costs; and
- contingency allowances.

Supporting Agency acceptance will evaluate the technical and administrative issues and concerns the agencies may have regarding each of the alternatives. Acceptance will also focus on legal issues and compliance with state statutes and regulations. ***Community acceptance*** will incorporate public concerns into the analyses of the alternatives.

The final step of this analysis is to conduct a comparative analysis of the alternatives. The analysis will include a discussion of the alternative's relative strengths and weaknesses with respect to each of the criteria and how reasonable key uncertainties could change expectations of their relative performance.

Once completed, this evaluation will be used to select the preferred alternative(s). The selection of the preferred alternative(s) will be documented in a Record of Decision (ROD) by the DEQ/MWCB. A public meeting to present the alternatives will be conducted and relevant oral and written comments will be addressed in writing.

8.1 QUANTITATIVE EVALUATION OF THRESHOLD CRITERIA

In the following detailed evaluations of the threshold criteria, each reclamation alternative contains quantitative estimates of risk reduction as well as estimates regarding whether ARARs would be attained by implementing the alternative. To quantitatively assess the threshold criteria (overall protection of human health and the environment and attainment of ARARs), the exposure pathways of concern that were identified in the baseline risk assessment (human health and ecologic) were evaluated to determine the risk reduction required to achieve the desired residual risk level (Hazard Quotient ≤ 1 and Ecologic Quotient ≤ 1). Each alternative was then modeled to ascertain the degree of risk reduction achieved, either through reduced contaminant loadings to an exposure pathway or reduced surface area available for certain exposures. The resulting risk reduction estimates are then compared to one another to determine whether the relative risk reduction provided by a specific alternative is greater than another; these risk reductions are also compared to the reduction required to alleviate excess risk via the specific pathway or media, as determined in the risk assessments. The risk reduction models also estimate resultant contaminant concentrations in the various media, which are then compared to media- and contaminant-specific ARARs. The groundwater model uses an on-site, downgradient exposure point, while the surface water/sediment model uses the sample station location below the sources at the site on Frohner Meadows Creek as the evaluation point.

Modeling estimates and assumptions are used in an attempt to quantify risk reduction and determine whether ARARs would be attained. In the course of performing this quantitative analysis, several assumptions and estimates are necessarily employed. Some of the assumptions are based on standard CERCLA risk assessment guidance, while others are based on-site-specific observations and professional judgements. Many of the estimates are based on conservative (worst case) scenarios, but since alternatives are compared to one another on a relative basis, these assumptions are consistent. The evaluation findings should, therefore, not be considered absolute (e.g., ARARs); however, the relative risk reduction differences between alternatives are meaningful and can be used to evaluate these criteria.

The human health baseline risk assessments determined that the pathways and CoCs at the Frohner site were soil ingestion of As and Pb and water ingestion of Pb (refer to Section 5.0). To effect risk reduction for these contaminants via the corresponding pathways, two scenarios have been modeled: a recreational exposure and a residential exposure. Each reclamation alternative is modeled for the two scenarios and the resultant risk reductions are compared to the reduction required to achieve these levels of protectiveness (recreational and residential): non-carcinogenic As via soil ingestion - 100% (residential), 92% (recreational); Pb via soil ingestion 96% (residential), 51% (recreational); and, Pb via water ingestion 98% (residential). Refer to Table 6-4 for pathway- and contaminant-specific risk reduction goals.

The ecologic risk assessment identified two exposure scenarios: Frohner Meadows Creek aquatic life receptors exposed to Cd and Zn in surface water, and Pb, Zn, and As in sediments; and plant phytotoxicity to Pb and As. The aquatic life scenario requires a surface water loading reduction of 93% to achieve ambient water quality criteria standards (acute-Zn); sediment concentrations require a 91% reduction in additional sediment loading to the creek to achieve preliminary sediment quality criteria - median effect range (As). The plant phytotoxicity scenario requires a 99% reduction in surface concentrations or area to achieve no phytotoxic effects from As.

The three exposure pathways were modeled to evaluate the relative risk reductions and attainment of ARARs afforded by each alternative. These calculations involved a combination of measured data collected at the site (waste and surface water concentrations), and modeled impacts (e.g., groundwater loading). A discussion of how the evaluations were performed and the assumptions used follows for each pathway.

The groundwater pathway was modeled using a simple mathematical model which utilized two components: estimates of leachate concentrations for precipitation water that flows through the waste sources and/or repository and ultimately into groundwater; and estimates of the rate that this water flows through the wastes and/or repository (flux). The first component, leachate concentrations, were obtained by using the TCLP analyses performed during the 1999 RI on composite samples of the waste sources. The second component, water flux through the sources, was estimated using the HELP (Version 3.01) model which uses a variety of site meteorological and physical data to determine the water balance at the site, including estimating the volume of water flux through the bottom of an impoundment. Each source was evaluated, as was the background groundwater shed. Assumptions used to evaluate groundwater impacts (loadings) include the following: inputs from the sources and background were summed, which has the effect of assuming complete dilution and not considering any other contaminant attenuation mechanisms; repository loads were summed with the other loads as a total loading to groundwater.

The surface water pathway was also modeled using a simple mathematical model which utilized two components: measured surface water concentrations above and below the site wastes; and an estimate of the relative increases in surface water loading provided by each source, based on relative contaminant concentrations in each source, the area of the source, and the proximity of each source to a surface water conveyance.

Assumptions used to evaluate surface water impacts (loadings) include the following: alternatives that employed covers or caps were assigned a 65% long-term effectiveness for preventing erosion into surface water; sources placed in a repository were assumed to have been 90% removed from exposures via this pathway; and sources moved off-site were assumed to have been 100% removed from exposures via this pathway. Surface water modeling considered an exposure point concentration in Frohner Meadows Creek that drains the wastes at the Frohner site.

The soil exposure pathways were empirically modeled using only reductions in surface area to estimate reduction in exposures. This pathway also assumed a 65% long-term effectiveness for maintaining adequate cover to prevent exposure due to the possibility of long-term deterioration of the clean soil cover. Sources placed in a repository or moved off-site were assumed to have been 100% removed from exposures via this pathway.

8.2 ALTERNATIVE 1: NO ACTION

The no action alternative is required for analysis by CERCLA and the NCP when evaluating alternatives in detail; the no action alternative is used to provide a baseline for comparing other alternatives. Under this alternative, no permanent reclamation activities would be implemented. Consequently, long-term human health and environmental risks associated with the on-site contamination would remain unchanged, with the contaminant sources at the site continuing to pose a threat to the human health and environmental resources.

8.2.1 Overall Protection of Human Health and the Environment

The no action alternative provides no control of exposures to contaminated materials and no reduction in risk to human health or the environment. It allows for the continued migration of contaminants and further degradation of groundwater and surface water quality.

Protection of human health would not be achieved under the no action alternative. Prevention of human exposure to CoCs via the pathways of concern, as identified in the human health risk assessment (refer to Section 5.0), would not occur. Soil ingestion exposure to As and Pb via contaminated surface soil and water ingestion exposure to Pb via contaminated groundwater would not be reduced, meeting none of the risk reduction levels.

Protection of the environment would also not be achieved under the no action alternative. Prevention of ecologic exposures via all the scenarios identified in the ecologic risk assessment, would not occur: aquatic life exposure to Cd and Zn via water and Pb, Zn, and As via sediment; and plant phytotoxicity to As and Pb.

A risk reduction achievement matrix (Table 8-1) was developed to assess whether the alternative affords sufficient protection to human health and the environment for the pathways and CoCs identified in the human health risk assessment (Section 5.1) and the ecological risk assessment (Section 5.2). The conclusions presented in the table are based on worst-case modeling results subject to the limitations and assumptions used in the models (see Section 8.1 for discussion).

TABLE 8-1
RISK REDUCTION ACHIEVEMENT MATRIX FOR ALTERNATIVE 1

ALTERNATIVE 1	As	Cd	Cu	Pb	Zn	OVERALL
Human Health Exposure Pathways:						
Soil Ingestion	None	Res.	Res.	None	Res.	None
Water Ingestion	Res.	Res.	Res.	Recr.	Res.	Recr.
Ecologic Exposure Pathways:						
Surface Water	--	No	--	--	No	No
Sediments	No	--	--	No	No	No
Plant Phytotoxicity	No	--	--	No	--	No

-- = Risk reduction not required for the contaminant for that pathway.
None = Does not achieve required risk reduction for any exposure scenario.
Recr. = Achieves required risk reduction for the recreational exposure scenario.
Res. = Achieves required risk reduction for the residential exposure scenario (most protective).

8.2.2 Compliance with ARARs

A comprehensive list of federal and state ARARs has been developed for the Frohner site and is summarized in Section 4.0 and presented in detail in Appendix B. ARARs are divided into contaminant-specific, location-specific, and action-specific requirements. Contaminant-specific ARARs are waste-related requirements, which specify how a waste must be managed, treated, and/or disposed depending upon the classification of the waste material. Location-specific ARARs specify how the remedial activities must take place depending upon where the wastes are physically located (i.e., in a stream or floodplain, wilderness area, or sensitive environment, etc.), or where the wastes may be treated or disposed, and what authorizations (permits) may be required. Action-specific ARARs are technology- or activity-based requirements, or are limitations on actions taken with respect to hazardous substances. Action-specific ARARs do not determine the preferred reclamation alternative, but indicate how the selected alternative must be achieved.

Under the no action alternative, no contaminated materials would be treated, removed, or actively managed. Consequently, the no action alternative would not satisfy federal or state ARARs. A water quality ARARs attainment matrix (Table 8-2) was developed to assess whether the alternative can achieve ARARs for those contaminants and media where they are exceeded. The conclusions presented in the table are based on worst-case modeling results subject to the limitations and assumptions used in the models (see Section 8.1 for discussion).

TABLE 8-2
WATER QUALITY ARARS ATTAINMENT FOR ALTERNATIVE 1

ALTERNATIVE 1	As	Cd	Cu	Pb	Zn
On-site Groundwater (μg/L)	10.8	0.2	NM	635	NM
On-site Surface water (μg/L)	22.0	4.8	7.0	14.3	908
On-site Groundwater ARARs	Yes	Yes	--	No	--
On-site Surface Water ARARs	No	No	Yes	Yes	No

Groundwater ARARs are State HHSs.
Surface water ARARs are State HHSs or Acute AWQC, whichever is lower.
NM = Contaminant not modeled (Cu and Zn not included in TCLP suite).

On-site groundwater would not meet water quality ARARs for Pb. On-site surface water would exceed water quality ARARs for As, Cd, and Zn (Acute AWQC).

8.2.3 Long-Term Effectiveness and Permanence

No controls or long-term measures would be placed on the contaminated materials at the site; consequently, all current and future risks would remain the same as described in the baseline risk assessment (Section 5.0). Therefore, the no action alternative would not be effective at minimizing risks from exposure to these materials. The time required until reclamation objectives are reached (by natural contaminant degradation and erosion) would be indefinite and would most likely be measured in terms of geologic time frames.

8.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The no action alternative would provide no reduction in toxicity, mobility, or volume of the contaminated materials.

8.2.5 Short-Term Effectiveness

In the short-term, the no action alternative would pose no additional threats to the community or the environment because the current site conditions would not be changed. The identical level of risk as identified in the risk assessment (see Section 5.0) would continue to exist in the short and long-term.

8.2.6 Implementability

There would be no implementability concerns posed by the no action alternative since no action would be taken.

8.2.7 Costs

The cost for implementing this alternative would be zero, since no action would be taken.

8.3 ALTERNATIVE 3a: CONSOLIDATION AND IN-PLACE CONTAINMENT-SOIL CAP

Generally, in-place containment strategies for reclaiming mined lands involve establishing vegetation on the surfaces of the solid media contaminant sources. The purpose of establishing vegetation is to stabilize the surface (provide erosion protection) and to decrease net infiltration through the waste medium by increasing evapotranspiration processes. Containment technologies may involve establishing vegetation directly on the waste source or may involve applying a cover over the waste source upon which the vegetation is established. Covers may range from a simple, single-layered soil cover to a complex, multi-layered cover consisting of various composite materials.

Alternative 3a consists of placing a one foot coversoil cap on the surface of the completed waste consolidation area (WR3, WR4, WR7, TP1, and SSTs) and on the graded wastes contained in-place (WR1, WR2, WR5, and WR6) (refer to Section 7.3.1.3).

8.3.1 Overall Protection of Human Health and the Environment

This alternative would provide a means of reducing soil ingestion exposure to the CoCs and would stabilize the surfaces of the sources with respect to migration to surface water. The reduction in risk to human health and the environment would not be sufficient to achieve the all the risk reduction dictated by the risk assessment. Alternative 3a would allow for the continued, though vastly reduced, migration of contaminants to groundwater and surface water, and it does provide significant but insufficient reduction of soil ingestion exposures.

Some protection of human health would be achieved under this alternative. Reduction of human exposures to CoCs via the pathways of concern, as identified in the human health risk assessment, would occur. Soil ingestion exposure to As and Pb via contaminated surface soil would be reduced, but neither would be reduced enough to meet the residential risk reduction levels; Pb would be reduced enough to meet the recreational risk levels, but As would not.

Limited protection of the environment would also be achieved under this alternative. Reduction of one ecologic exposure, of the scenarios identified in the ecologic risk assessment, would not occur: plant phytotoxicity to As and Pb would not be sufficiently reduced.

A risk reduction achievement matrix (Table 8-3) was developed to assess whether the alternative affords sufficient protection to human health and the environment for the pathways and CoCs identified in the human health risk assessment (Section 5.1) and the ecological risk assessment (Section 5.2). The conclusions presented in the table are based on worst-case modeling results subject to the limitations and assumptions used in the models (see Section 8.1 for discussion).

TABLE 8-3
RISK REDUCTION ACHIEVEMENT MATRIX FOR ALTERNATIVE 3a

ALTERNATIVE 3a	As	Cd	Cu	Pb	Zn	OVERALL
Human Health Exposure Pathways:						
Soil Ingestion	None	Res.	Res.	Recr.	Res.	None
Water Ingestion	Res.	Res.	Res.	Recr.	Res.	Recr.
Ecologic Exposure Pathways:						
Surface Water	--	Yes	--	–	Yes	Yes
Sediments	Yes	--	--	Yes	Yes	Yes
Plant Phytotoxicity	No	--	--	No	--	No

-- = Risk reduction not required for the contaminant for that pathway.
None = Does not achieve required risk reduction for any exposure scenario.
Recr. = Achieves required risk reduction for the recreational exposure scenario.
Res. = Achieves required risk reduction for the residential exposure scenario (most protective).

8.3.2 Compliance with ARARs

There are no ARARs that apply to in-place stabilization/containment of contaminated solid media. Some water quality ARARs are not expected to be achieved under this alternative. A water quality ARARs attainment matrix (Table 8-4) was developed to assess whether the alternative can achieve ARARs for those contaminants and media where they are exceeded. The conclusions presented in the table are based on worst-case modeling results subject to the limitations and assumptions used in the models (see Section 8.1 for discussion).

TABLE 8-4
WATER QUALITY ARARS ATTAINMENT FOR ALTERNATIVE 3a

ALTERNATIVE 3a	As	Cd	Cu	Pb	Zn
On-site Groundwater (µg/L)	2.2	0.1	NM	26	NM
On-site Surface water (µg/L)	12	0.3	1.3	4.4	46.6
On-site Groundwater ARARs	Yes	Yes	--	No	--
On-site Surface Water ARARs	Yes	Yes	Yes	Yes	Yes

Groundwater ARARs are State HHSs.
Surface water ARARs are State HHSs or Acute AWQC, whichever is lower.
NM = Contaminant not modeled (Cu and Zn not included in TCLP suite).

On-site groundwater would not meet water quality ARARs for Pb. On-site surface water would meet water quality ARARs (Acute AWQC).

8.3.3 Long-Term Effectiveness and Permanence

Under this alternative, the consolidated waste rock area and waste rock dumps will be graded, capped with cover soils, and revegetated. The revegetated caps would stabilize the sources by providing an erosion-resistant, vegetated surface that would provide protection from surface water and wind erosion, and would reduce net infiltration through the contaminated media by increasing evapotranspiration processes. Run-on controls and grading would reduce infiltration by directing upgradient flows around the area, as well as by eliminating ponding and promoting run-off from the caps. The caps and run-on controls would have to be maintained to ensure that they perform as designed and consequently, long-term monitoring and frequent inspection and maintenance would be required. The caps would be susceptible to possible settlement, erosion, and disruption of cover integrity by vehicles, deep-rooting vegetation, and burrowing animals. However, the cover could be easily inspected and the required maintenance could be easily determined and performed.

The cover soils and revegetation would consequently reduce the threat of direct contact and inhalation of airborne contaminants by on-site and nearby receptors. The long-term effectiveness of the cap would be enhanced by carefully determining proper amendments, and selecting appropriate plant species, adapted to short growing seasons and high altitudes (as opposed to selecting natives species exclusively).

In the long-term, the water quality and sediment environment (benthic community) in Frohner Meadows Creek are expected to be improved by implementing this alternative. Also the downstream wetland and fishery is expected to benefit because the contaminant sources potentially impacting the stream would be stabilized with respect to surface water erosion. The long-term effectiveness should be monitored by frequent inspections of the capped/reclaimed wastes (subsequent maintenance should be performed when necessary) and extended surface water and sediment monitoring in Frohner Meadows Creek.

8.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The primary objective of this alternative is to provide a reduction in contaminant mobility: the volume or toxicity of the contaminant would not be reduced by implementing this alternative. Consolidating and covering and revegetating the mine waste sources would stabilize these sources and reduce contaminant mobility via surface water and wind erosion. Groundwater impacts would also be reduced by decreasing infiltration through the waste sources by increasing the evapotranspiration process and by grading the reclaimed areas to prevent ponding and promote run-off. Removing the tailings and waste rock located immediately adjacent to the creek and consolidating these wastes away from the creek would reduce contaminant mobility and surface water impacts by increasing the distance between these wastes and the creek and eliminating direct contact with Frohner Meadows Creek. Based on modeling results, this alternative is expected to reduce the mobility of the on-site contaminant to an extent that would result in an overall human health risk reduction (all pathways and routed of exposure considered) of 68% and an overall ecological risk reduction of 88%.

8.3.5 Short-Term Effectiveness

It is anticipated that the construction phase of this alternative would be accomplished in a relatively short period of time (one construction season); therefore, impacts associated with construction would be short-term. Short-term impacts to the surrounding community are expected to be minimal because of the remote location of the project site and the lack of a resident population. However, short-term air quality impacts to the surrounding environment may occur. On-site workers would be adequately protected during the construction phase by utilizing appropriate personal protective equipment and by following proper operating and safety procedures. Control of fugitive dust emissions would be provided by applying water (via water truck) to surfaces receiving heavy vehicular traffic.

Under this alternative wastes, which are located directly in or near Frohner Meadows Creek, would be removed and/or recontoured to stabilize the creek channel. These construction activities would occur directly in or very near the current stream channel and could cause significant short-term adverse impacts to the water quality in the creek. For these reasons the creek would temporarily be diverted away from construction areas as needed to minimize short-term impacts. Stormwater run-off from other general construction activities may also cause short-term adverse impacts to water quality in the creek. Traditional construction BMPs would be employed to address these sources, and can effectively reduce adverse impacts on surface water from the construction activities.

8.3.6 Implementability

This alternative is both technically and administratively feasible, and could be implemented in a relatively short period of time (one construction season). The excavation, consolidation, grading, capping, and revegetation steps required are considered conventional construction practices; materials and construction methods are readily available, also, design methods and requirements are well documented and well understood. However, the construction steps required to implement this alternative are considered moderately difficult (due, in part, to the rough terrain, potentially complex construction sequencing, and the remote location), and should only be performed by experienced contractors utilizing the appropriate equipment.

8.3.7 Costs

The total present worth cost for Alternative 3a has been estimated at $ 305,288, which represents the remediation of all solid media contaminant sources at the Frohner Mine and Millsite. Table C-1 (Appendix C) presents the cost details associated with implementing this alternative.

8.4 ALTERNATIVE 3b: CONSOLIDATION AND IN-PLACE CONTAINMENT-IMPERMEABLE CAP

Alternative 3b involves recontouring waste rock dumps WR1, WR2, WR5, and WR6 (similar to Alternative 3a) and excavating and consolidating waste sources WR3, WR4, WR7, TP1 and SSTs away from Frohner Meadows Creek, placing a lined, 24-inch coversoil cap on the surface of the consolidation area, amending the cover soil as required and revegetating (refer to Section 7.3.1.3).

8.4.1 Overall Protection of Human Health and the Environment

This alternative would provide a means of reducing soil ingestion exposure to the CoCs and would stabilize the surfaces of the sources with respect to migration to surface water. The reduction in risk to human health and the environment would not be sufficient to achieve the all the risk reduction dictated by the risk assessment. Alternative 3b would allow for the continued, though vastly reduced, migration of contaminants to groundwater and surface water, and it does provide significant but insufficient reduction of soil ingestion exposures.

Some protection of human health would be achieved under this alternative. Reduction of human exposures to CoCs via the pathways of concern, as identified in the human health risk assessment, would occur. Soil ingestion exposure to As and Pb via contaminated surface soil would be reduced, but neither would be reduced enough to meet the residential risk reduction levels; Pb would be reduced enough to meet the recreational risk levels, but As would not.

Limited protection of the environment would also be achieved under this alternative. Reduction of one ecologic exposure, of the scenarios identified in the ecologic risk assessment, would not occur: plant phytotoxicity to As and Pb would not be sufficiently reduced.

A risk reduction achievement matrix (Table 8-5) was developed to assess whether the alternative affords sufficient protection to human health and the environment for the pathways and CoCs identified in the human health risk assessment (Section 5.1) and the ecological risk assessment (Section 5.2). The conclusions presented in the table are based on worst-case modeling results subject to the limitations and assumptions used in the models (see Section 8.1 for discussion).

TABLE 8-5
RISK REDUCTION ACHIEVEMENT MATRIX FOR ALTERNATIVE 3b

ALTERNATIVE 3b	As	Cd	Cu	Pb	Zn	OVERALL
Human Health Exposure Pathways:						
Soil Ingestion	None	Res.	Res.	Recr.	Res.	None
Water Ingestion	Res.	Res.	Res.	Recr.	Res.	Recr.
Ecologic Exposure Pathways:						
Surface Water	--	Yes	--	–	Yes	Yes
Sediments	Yes	--	--	Yes	Yes	Yes
Plant Phytotoxicity	No	--	--	No	--	No

-- = Risk reduction not required for the contaminant for that pathway.
None = Does not achieve required risk reduction for any exposure scenario.
Recr. = Achieves required risk reduction for the recreational exposure scenario.
Res. = Achieves required risk reduction for the residential exposure scenario (most protective).

8.4.2 Compliance with ARARs

There are no ARARs that apply to in-place stabilization/containment of contaminated solid media. Some water quality ARARs are not expected to be achieved under this alternative. A water quality ARARs attainment matrix (Table 8-6) was developed to assess whether the alternative can achieve ARARs for those contaminants and media where they are exceeded. The conclusions presented in the table are based on worst-case modeling results subject to the limitations and assumptions used in the models (see Section 8.1 for discussion).

TABLE 8-6
WATER QUALITY ARARS ATTAINMENT FOR ALTERNATIVE 3b

ALTERNATIVE 3b	As	Cd	Cu	Pb	Zn
On-site Groundwater (μg/L)	2.2	0.1	NM	26	NM
On-site Surface water (μg/L)	12	0.3	1.2	4.3	43.4
On-site Groundwater ARARs	Yes	Yes	--	No	--
On-site Surface Water ARARs	Yes	Yes	Yes	Yes	Yes

Groundwater ARARs are State HHSs.
Surface water ARARs are State HHSs or Acute AWQC, whichever is lower.
NM = Contaminant not modeled (Cu and Zn not included in TCLP suite).

On-site groundwater would not meet water quality ARARs for Pb. On-site surface water would meet water quality ARARs (Acute AWQC).

8.4.3 Long-Term Effectiveness and Permanence

Under this alternative, some of the waste rock dumps will be graded in-place and capped with cover soils and revegetated; some waste sources will be consolidated and capped with a multi-layered, lined cap. The revegetated caps would stabilize these sources by providing an erosion-resistant, vegetated surface that would provide protection from surface water and wind erosion, and would reduce net infiltration through the contaminated media by increasing evapotranspiration processes. Run-on controls and grading would reduce infiltration by directing upgradient flows around the area, as well as by eliminating ponding and promoting run-off from the caps. The caps and run-on controls would have to be maintained to ensure that they perform as designed and consequently, long-term monitoring and frequent inspection and maintenance would be required. The caps would be susceptible to possible settlement, erosion, and disruption of cover integrity by vehicles, deep-rooting vegetation, and burrowing animals. However, the cover could be easily inspected and the required maintenance could be easily determined.

The cover soils and revegetation would consequently reduce the threat of direct contact and inhalation of airborne contaminant by on-site and nearby receptors. The long-term effectiveness of the cap would be enhanced by carefully determining proper amendments, and selecting appropriate plant species, adapted to short growing seasons and high altitudes (as opposed to selecting natives species exclusively).

In the long-term, the water quality and sediment environment (benthic community) in Frohner Meadows Creek are expected to be improved by implementing this alternative. Also, the downstream wetland and fishery is expected to benefit because the contaminant sources potentially impacting the stream would be stabilized with respect to surface water erosion. The long-term effectiveness should be monitored by frequent inspections of the capped/reclaimed wastes (subsequent maintenance should be performed when necessary) and extended surface water and sediment monitoring in Frohner Meadows Creek.

8.4.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The primary objective of this alternative is to provide a reduction in contaminant mobility: the volume or toxicity of the contaminant would not be reduced by implementing this alternative. Consolidating and covering and revegetating the mine waste sources would stabilize these sources and reduce contaminant mobility via surface water and wind erosion. Groundwater impacts would also be reduced by decreasing infiltration through the waste sources by increasing the evapotranspiration process and by grading the reclaimed areas to prevent ponding and promote run-off. Removing the tailings and waste rock located immediately adjacent to the creek and consolidating these wastes away from the creek would reduce contaminant mobility and surface water impacts by increasing the distance between these wastes and the creek and eliminating direct contact with Frohner Meadows Creek. Based on modeling results, this alternative is expected to reduce the mobility of the on-site contaminant to an extent that would result in an overall human health risk reduction (all pathways and routed of exposure considered) of 90% and an overall ecological risk reduction of 95%.

8.4.5 Short-Term Effectiveness

It is anticipated that the construction phase of this alternative would be accomplished in a relatively short period of time (on construction season); therefore, impacts associated with construction would be short-term. Short-term impacts to the surrounding community are expected to be minimal because of the remote location of the project site and the lack of a resident population. However, short-term air quality impacts to the surrounding environment may occur. On-site workers would be adequately protected during the construction phase by utilizing appropriate personal protective equipment and by following proper operating and safety procedures. Control of fugitive dust emissions would be provided by applying water (via water truck) to surfaces receiving heavy vehicular traffic.

Under this alternative wastes, which are located directly in or near Frohner Meadows Creek, would be removed and/or recontoured to stabilize the creek channel. These construction activities would occur directly in or very near the current stream channel and may cause significant short-term adverse impacts to the water quality in the creek. For these reasons the creek would temporarily be diverted away from construction areas as needed to minimize short-term impacts. Stormwater run-off from other general construction activities may also cause short-term adverse impacts to water quality in the creek. Traditional construction BMPs would be employed to address these sources, and can effectively reduce adverse impacts on surface water from the construction activities.

8.4.6 Implementability

This alternative is both technically and administratively feasible, and could be implemented in a relatively short period of time (one construction season). The excavation, consolidation, grading, capping, and revegetation steps required are considered conventional construction practices; materials and construction methods are readily available; also, design methods and requirements are well documented and well understood. However, the construction steps required to implement this alternative are considered moderately difficult (due, in part, to the rough terrain, potentially complex construction sequencing, and the remote location), and should only be performed by experienced contractors utilizing the appropriate equipment.

8.4.7 Costs

The total present worth cost for Alternative 3b has been estimated at $400,856, which represents the remediation of all solid media contaminant sources at the Frohner Mine and Millsite. Table C-2 (Appendix C) presents the cost details associated with implementing this alternative.

8.5 ALTERNATIVE 4a: REMOVAL TO ON-SITE REPOSITORY WITH CAP AND LINER

Alternative 4a consists of excavating and disposing of all waste sources at the Frohner Mine and Millsite in a repository located southwest of the mine site. The repository would include a bottom liner and leachate collection system with a multi-layered lined cap over the waste materials (Figure 7-4).

8.5.1 Overall Protection of Human Health and the Environment

This alternative would provide a means of reducing soil and groundwater ingestion exposure to the CoCs and would stabilize the surfaces of the sources with respect to migration to surface water.

Significant protection of human health would be achieved under this alternative. Reduction of human exposures to CoCs via the pathways of concern, as identified in the human health risk assessment, would occur. Soil ingestion exposure to As and Pb via contaminated surface soil would meet the residential level.

Protection of the environment would also be achieved under this alternative. Reduction of ecologic exposures, via the scenarios identified in the ecologic risk assessment, would be achieved: aquatic life exposure to Cd and Zn via water would be sufficiently reduced; and plant phytotoxicity to As and Pb would be sufficiently reduced.

A risk reduction achievement matrix (Table 8-7) was developed to assess whether the alternative affords sufficient protection to human health and the environment for the pathways and CoCs identified in the human health risk assessment (Section 5.1) and the ecological risk assessment (Section 5.2). The conclusions presented in the table are based on worst-case modeling results subject to the limitations and assumptions used in the models (see Section 8.1 for discussion).

TABLE 8-7
RISK REDUCTION ACHIEVEMENT MATRIX FOR ALTERNATIVE 4a

ALTERNATIVE 4a	As	Cd	Cu	Pb	Zn	OVERALL
Human Health Exposure Pathways:						
Soil Ingestion	Res.	Res.	Res.	Res.	Res.	Res.
Water Ingestion	Res.	Res.	Res.	Res.	Res.	Res.
Ecologic Exposure Pathways:						
Surface Water	--	Yes	--	–	Yes	Yes
Sediments	Yes	--	--	Yes	Yes	Yes
Plant Phytotoxicity	Yes	--	--	Yes	--	Yes

-- = Risk reduction not required for the contaminant for that pathway.
None = Does not achieve required risk reduction for any exposure scenario.
Recr. = Achieves required risk reduction for the recreational exposure scenario.
Res. = Achieves required risk reduction for the residential exposure scenario (most protective).

8.5.2 Compliance with ARARs

There are no ARARs that are required to be met for contaminated solid media. Water quality ARARs are expected to be achieved by this alternative. A water quality ARARs attainment matrix (Table 8-8) was developed to assess whether the alternative can achieve ARARs for those contaminants and media where they are exceeded. The conclusions presented in the table are based on worst-case modeling results subject to the limitations and assumptions used in the models (see Section 8.1 for discussion).

TABLE 8-8
WATER QUALITY ARARS ATTAINMENT FOR ALTERNATIVE 4a

ALTERNATIVE 4a	As	Cd	Cu	Pb	Zn
On-site Groundwater (μg/L)	2.0	0.04	NM	1.9	NM
On-site Surface water (μg/L)	12	0.3	1.2	4.3	42.1
On-site Groundwater ARARs	Yes	Yes	--	Yes	--
On-site Surface Water ARARs	Yes	Yes	Yes	Yes	Yes

Groundwater ARARs are State HHSs.
Surface water ARARs are State HHSs or Acute AWQC, whichever is lower.
NM = Contaminant not modeled (Cu and Zn not included in TCLP suite).

On-site groundwater would meet water quality ARARs. On-site surface water would also meet water quality ARARs (Acute AWQCs).

8.5.3 Long-Term Effectiveness and Permanence

Under this alternative, the constructed repository would have to be maintained to ensure that it continues to perform as designed. The actual design life of the repository is not certain, and consequently, long-term monitoring and routine inspection and maintenance would be required. The repository cap would likely be the component most vulnerable to any damage or degradation that might occur. Multi-layered caps are susceptible to settlement, ponding of surface water, erosion, and disruption of cover integrity by vehicles, deep-rooting vegetation, and burrowing animals. However, the cap could easily be inspected and the required maintenance could be easily determined and performed. The composite cap and bottom liner system would effectively isolate the waste materials and consequently reduce the threat of direct contact and inhalation of airborne contaminant by on-site and nearby receptors. The long-term effectiveness of the cap would be enhanced by carefully determining proper amendments, and selecting appropriate plant species, adapted to short growing seasons and high altitudes (as opposed to selecting natives species exclusively).

Run-on controls and proper grading would reduce infiltration by directing upgradient flows around the repository, as well as by eliminating ponding and promoting run-off from the cap.

In the long-term, the water quality and sediment environment (benthic community) in Frohner Meadows Creek are expected to be improved by implementing this alternative. Also, the downstream wetland and fishery is expected to benefit because the contaminant sources potentially impacting the stream would be stabilized with respect to surface water erosion. The long-term effectiveness should be monitored by frequent inspections of the capped/reclaimed wastes (subsequent maintenance should be performed when necessary) and extended surface water and sediment monitoring in Frohner Meadows Creek.

8.5.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The primary objective of this alternative is to provide a significant reduction in contaminant mobility: the volume or toxicity of the contaminant would not be reduced by implementing this alternative. The primary waste sources would be rendered immobile in an engineered facility, which is protected from erosion problems. The engineered facility would eliminate the direct contact and surface water erosion pathways, and would greatly reduce leaching of contaminants to groundwater. Based on modeling results, this alternative is expected to reduce the mobility of the on-site contaminant to an extent that would result if an overall human health risk reduction (all pathways and all routes of exposure considered) of 100% and an overall ecological risk reduction of 98%.

8.5.5 Short-Term Effectiveness

It is anticipated that the construction phase of this alternative would be accomplished in a relatively short period of time (on construction season); therefore, impacts associated with construction would be short-term. Short-term impacts to the surrounding community are expected to be minimal because of the remote location of the project site and the lack of a resident population. However, short-term air quality impacts to the surrounding environment may occur. On-site workers would be adequately protected during the construction phase by utilizing appropriate personal protective equipment and by following proper operating and safety procedures. Control of fugitive dust emissions would be provided by applying water (via water truck) to surfaces receiving heavy vehicular traffic.

Under this alternative wastes, which are located directly in or near Frohner Meadows Creek, would be removed and/or recontoured to stabilize the creek channel. These construction activities would occur directly in or very near the current stream channel and may cause significant short-term adverse impacts to the water quality in the creek. For these reasons the creek would temporarily be diverted away from construction areas as needed to minimize short-term impacts. Stormwater run-off from other general construction activities may also cause short-term adverse impacts to water quality in the creek. Traditional construction BMPs would be employed to address these sources, and can effectively reduce adverse impacts on surface water from the construction activities.

8.5.6 Implementability

This alternative is both technically and administratively feasible, and could be implemented in a relatively short period of time (one construction season). The excavation, consolidation, grading, capping, and revegetation steps required are considered conventional construction practices; materials and construction methods are readily available; also, design methods and requirements are well documented and well understood. However, the construction steps required to implement this alternative are considered moderately difficult (due, in part, to the rough terrain, potentially complex construction sequencing, and the remote location), and should only be performed by experienced contractors utilizing the appropriate equipment.

8.5.7 Costs

The total present worth cost for Alternative 4a has been estimated at $651,506, which represents the remediation of all solid media contaminant sources at the Frohner Mine and Millsite. Table C-3 (Appendix C) presents the cost details associated with implementing this alternative.

8.6 <u>ALTERNATIVE 4b: REMOVAL TO ON-SITE REPOSITORY WITH CAP ONLY</u>

Alternative 4b consists of excavating and disposing of all waste sources at the Frohner Mine and Millsite in a repository located southwest of the mine site. The repository would entail a multi-layered cap with no bottom liner (Figure 7-5).

8.6.1 Overall Protection of Human Health and the Environment

This alternative would provide a means of significantly reducing soil ingestion and groundwater ingestion exposure to the CoCs and would stabilize the surfaces of the sources with respect to migration to surface water.

Significant protection of human health would be achieved under this alternative. Reduction of human exposures to CoCs via the pathways of concern, as identified in the human health risk assessment, would occur. Soil ingestion exposure via contaminated surface soil would be meet the residential risk level.

Protection of the environment would also be achieved under this alternative. Reduction of ecologic exposures, via the scenarios identified in the ecologic risk assessment, would occur: aquatic life exposure via water and sediment would be sufficiently reduced; and plant phytotoxicity would also be sufficiently reduced.

A risk reduction achievement matrix (Table 8-9) was developed to assess whether the alternative affords sufficient protection to human health and the environment for the pathways and CoCs identified in the human health risk assessment (Section 5.1) and the ecological risk assessment (Section 5.2). The conclusions presented in the table are based on worst-case modeling results subject to the limitations and assumptions used in the models (see Section 8.1 for discussion).

TABLE 8-9
RISK REDUCTION ACHIEVEMENT MATRIX FOR ALTERNATIVE 4b

ALTERNATIVE 4b	As	Cd	Cu	Pb	Zn	OVERALL
Human Health Exposure Pathways:						
Soil Ingestion	Res.	Res.	Res.	Res.	Res.	Res.
Water Ingestion	Res.	Res.	Res.	Recr.	Res.	Recr.
Ecologic Exposure Pathways:						
Surface Water	--	Yes	--	–	Yes	Yes
Sediments	Yes	--	--	Yes	Yes	Yes
Plant Phytotoxicity	Yes	--	--	Yes	--	Yes

-- = Risk reduction not required for the contaminant for that pathway.
None = Does not achieve required risk reduction for any exposure scenario.
Recr. = Achieves required risk reduction for the recreational exposure scenario.
Res. = Achieves required risk reduction for the residential exposure scenario (most protective).

8.6.2 Compliance with ARARs

There are no ARARs that are required to be met for contaminated solid media. One water quality ARARs is not expected to be achieved by this alternative. A water quality ARARs attainment matrix (Table 8-10) was developed to assess whether the alternative can achieve ARARs for those contaminants and media where they are exceeded. The conclusions presented in the table are based on worst-case modeling results subject to the limitations and assumptions used in the models (see Section 8.1 for discussion).

TABLE 8-10
WATER QUALITY ARARS ATTAINMENT FOR ALTERNATIVE 4b

ALTERNATIVE 4b	As	Cd	Cu	Pb	Zn
On-site Groundwater (μg/L)	2.4	0.05	NM	42	NM
On-site Surface water (μg/L)	12	0.3	1.2	4.3	42
On-site Groundwater ARARs	Yes	Yes	--	No	--
On-site Surface Water ARARs	Yes	Yes	Yes	Yes	Yes

Groundwater ARARs are State HHSs.
Surface water ARARs are State HHSs or Acute AWQC, whichever is lower.
NM = Contaminant not modeled (Cu and Zn not included in TCLP suite).

On-site groundwater would not meet water quality ARARs for Pb. On-site surface water would meet water quality ARARs (Acute AWQCs).

8.6.3 Long-Term Effectiveness and Permanence

Under this alternative, the constructed repository would have to be maintained to ensure that it continues to perform as designed. The actual design life of the repository is not certain, and consequently, long-term monitoring and routine inspection and maintenance would be required. The repository cap would likely be the component most vulnerable to any damage or degradation that might occur. Multi-layered caps are susceptible to settlement, ponding of surface water, erosion, and disruption of cover integrity by vehicles, deep-rooting vegetation, and burrowing animals. However, the cap could easily be inspected and the required maintenance could be easily determined and performed. The composite cap would effectively isolate the waste materials and consequently reduce the threat of direct contact and inhalation of airborne contaminant by on-site and nearby receptors. The long-term effectiveness of the cap would be enhanced by carefully determining proper amendments, and selecting appropriate plant species, adapted to short growing seasons and high altitudes (as opposed to selecting natives species exclusively).

Run-on controls and proper grading would reduce infiltration by directing upgradient flows around the repository, as well as by eliminating ponding and promoting run-off from the cap.

In the long-term, the water quality and sediment environment (benthic community) in Frohner Meadows Creek are expected to be improved by implementing this alternative. Also, the downstream wetland and fishery is expected to benefit because the contaminant sources potentially impacting the stream would be stabilized with respect to surface water erosion. The long-term effectiveness should be monitored by frequent inspections of the capped/reclaimed wastes (subsequent maintenance should be performed when necessary) and extended surface water and sediment monitoring in Frohner Meadows Creek.

8.6.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The primary objective of this alternative is to provide a significant reduction in contaminant mobility: the volume or toxicity of the contaminant would not be reduced by implementing this alternative. The primary waste sources would be rendered immobile in an engineered facility, which is protected from erosion problems. The engineered facility would eliminate the direct contact and surface water erosion pathways, and would greatly reduce leaching of contaminants to groundwater. Based on modeling results, this alternative is expected to reduce the mobility of the on-site contaminant to an extent that would result in an overall human health risk reduction (all pathways and all routes of exposure considered) of 99% and an overall ecological risk reduction of 98%.

8.6.5 Short-Term Effectiveness

It is anticipated that the construction phase of this alternative would be accomplished in a relatively short period of time (on construction season); therefore, impacts associated with construction would be short-term. Short-term impacts to the surrounding community are expected to be minimal because of the remote location of the project site and the lack of a resident population. However, short-term air quality impacts to the surrounding environment may occur. On-site workers would be adequately protected during the construction phase by utilizing appropriate personal protective equipment and by following proper operating and safety procedures. Control of fugitive dust emissions would be provided by applying water (via water truck) to surfaces receiving heavy vehicular traffic.

Under this alternative, wastes which are located directly in or near Frohner Meadows Creek, would be removed and/or recontoured to stabilize the creek channel. These construction activities would occur directly in or very near the current stream channel and may cause significant short-term adverse impacts to the water quality in the creek. For these reasons the creek would temporarily be diverted away from construction areas as needed to minimize short-term impacts. Stormwater run-off from other general construction activities may also cause short-term adverse impacts to water quality in the creek. Traditional construction BMPs would be employed to address these sources, and can effectively reduce adverse impacts on surface water from the construction activities.

8.6.6 Implementability

This alternative is both technically and administratively feasible, and could be implemented in a relatively short period of time (one construction season). The excavation, consolidation, grading, capping, and revegetation steps required are considered conventional construction practices; materials and construction methods are readily available; also, design methods and requirements are well documented and well understood. However, the construction steps required to implement this alternative are considered moderately difficult (due, in part, to the rough terrain, potentially complex construction sequencing, and the remote location), and should only be performed by experienced contractors utilizing the appropriate equipment.

8.6.7 Costs

The total present worth cost for Alternative 4b has been estimated at $561,310, which represents the remediation of all solid media contaminant sources at the Frohner Mine and Millsite. Table C-4 (Appendix C) presents the cost details associated with implementing this alternative.

8.7 ALTERNATIVE 5a: PARTIAL REMOVAL TO ON-SITE REPOSITORY WITH CAP AND LINER

Alternative 5a consists of in-place containment of some of the waste sources (WR1 through WR6) and complete removal of wastes located near Frohner Meadows Creek (WR7, TP1, and SSTs) to the repository identified in Alternative 4. The repository would include a bottom liner and leachate collection system with a multi-layered cap over the waste materials (Figure 7-4).

8.7.1 Overall Protection of Human Health and the Environment

This alternative would provide a means of reducing soil ingestion exposure to the CoCs and would stabilize the surfaces of the primary sources with respect to migration to surface water. The reduction in risk to human health and the environment would not be sufficient to achieve the risk reductions dictated by the risk assessment. Alternative 5a would sufficiently reduce the migration of contaminants to surface water, and provides significant but insufficient reduction of soil and groundwater ingestion exposures.

Some protection of human health would be achieved under this alternative. Reduction of human exposures to CoCs via the pathways of concern, as identified in the human health risk assessment, would occur. Soil ingestion exposure to As and Pb via contaminated surface soil would be reduced, but neither would be reduced enough to meet the residential risk reduction levels; Pb would be reduced enough to meet the recreational risk levels, but As would not.

Limited protection of the environment would also be achieved under this alternative. Reduction of most ecologic exposures, via the scenarios identified in the ecologic risk assessment, would not occur: plant phytotoxicity to As and Pb would not be sufficiently reduced.

A risk reduction achievement matrix (Table 8-11) was developed to assess whether the alternative affords sufficient protection to human health and the environment for the pathways and CoCs identified in the human health risk assessment (Section 5.1) and the ecological risk assessment (Section 5.2). The conclusions presented in the table are based on worst-case modeling results subject to the limitations and assumptions used in the models (see Section 8.1 for discussion).

TABLE 8-11
RISK REDUCTION ACHIEVEMENT MATRIX FOR ALTERNATIVE 5a

ALTERNATIVE 5a	As	Cd	Cu	Pb	Zn	OVERALL
Human Health Exposure Pathways:						
Soil Ingestion	None	Res.	Res.	Recr.	Res.	None
Water Ingestion	Res.	Res.	Res.	Recr.	Res.	Recr.
Ecologic Exposure Pathways:						
Surface Water	--	Yes	--	--	Yes	Yes
Sediments	Yes	--	--	Yes	Yes	Yes
Plant Phytotoxicity	No	--	--	No	--	No

-- = Risk reduction not required for the contaminant for that pathway.
None = Does not achieve required risk reduction for any exposure scenario.
Recr. = Achieves required risk reduction for the recreational exposure scenario.
Res. = Achieves required risk reduction for the residential exposure scenario (most protective).

8.7.2 Compliance with ARARs

There are no ARARs that are required to be met for contaminated solid media. Water quality ARARs are expected to be achieved by this alternative. A water quality ARARs attainment matrix (Table 8-12) was developed to assess whether the alternative can achieve ARARs for those contaminants and media where they are exceeded. The conclusions presented in the table are based on worst-case modeling results subject to the limitations and assumptions used in the models (see Section 8.1 for discussion).

TABLE 8-12
WATER QUALITY ARARS ATTAINMENT FOR ALTERNATIVE 5a

ALTERNATIVE 5a	As	Cd	Cu	Pb	Zn
On-site Groundwater (µg/L)	2.1	0.05	NM	39	NM
On-site Surface water (µg/L)	12	0.3	1.2	4.4	44
On-site Groundwater ARARs	Yes	Yes	--	No	--
On-site Surface Water ARARs	Yes	Yes	Yes	Yes	Yes

Groundwater ARARs are State HHSs.
Surface water ARARs are State HHSs or Acute AWQC, whichever is lower.
NM = Contaminant not modeled (Cu and Zn not included in TCLP suite).

On-site groundwater would not meet water quality ARARs for Pb. On-site surface water would meet water quality ARARs (Acute AWQCs).

8.7.3 Long-Term Effectiveness and Permanence

Under this alternative, waste rock dumps WR1 through WR6 will be graded, capped with cover soils and revegetated. The revegetated caps would stabilize these sources by providing an erosion-resistant, vegetated surface that would provide protection from surface water and wind erosion, and would reduce net infiltration through the contaminated media by increasing evapotranspiration processes. Run-on controls and grading would reduce infiltration by directing upgradient flows around the area, as well as by eliminating ponding and promoting run-off from the caps. The caps and run-on controls would have to be maintained to ensure that they perform as designed, and consequently, long-term monitoring and frequent inspection and maintenance would be required. The caps would be susceptible to possible settlement, erosion, and disruption of cover integrity by vehicles, deep-rooting vegetation, and burrowing animals. However, the cover could be easily inspected and the required maintenance could be easily determined.

The cover soils and revegetation would consequently reduce the threat of direct contact and inhalation of airborne contaminant by on-site and nearby receptors. The long-term effectiveness of the cap would be enhanced by carefully determining proper amendments, and selecting appropriate plant species, adapted to short growing seasons and high altitudes (as opposed to selecting natives species exclusively).

The constructed repository would have to be maintained to ensure that it continues to perform as designed. The actual design life of the repository is not certain, and consequently, long-term monitoring and routine inspection and maintenance would be required. The repository cap would likely be the component most vulnerable to any damage or degradation that might occur. Multi-layered caps are susceptible to settlement, ponding of surface water, erosion, and disruption of cover integrity by vehicles, deep-rooting vegetation, and burrowing animals. However, the cap could easily be inspected and the required maintenance could be easily determined and performed. The composite cap would effectively isolate the waste materials and consequently reduce the threat of direct contact and inhalation of airborne contaminant by on-site and nearby receptors. The long-term effectiveness of the cap would be enhanced by carefully determining proper amendments, and selecting appropriate plant species, adapted to short growing seasons and high altitudes (as opposed to selecting natives species exclusively).

Run-on controls and proper grading would reduce infiltration by directing upgradient flows around the repository, as well as by eliminating ponding and promoting run-off from the cap.

In the long-term, the water quality and sediment environment (benthic community) in Frohner Meadows Creek are expected to be improved by implementing this alternative. Also the downstream wetland and fishery is expected to benefit because the contaminant sources potentially impacting the stream would be stabilized with respect to surface water erosion. The long-term effectiveness should be monitored by frequent inspections of the capped/reclaimed wastes (subsequent maintenance should be performed when necessary) and extended surface water and sediment monitoring in Frohner Meadows Creek.

8.7.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The primary objective of this alternative is to provide a significant reduction in contaminant mobility: the volume or toxicity of the contaminant would not be reduced by implementing this alternative. The primary waste sources would be rendered immobile in an engineered facility, which is protected from erosion problems. The engineered facility would eliminate the direct contact and surface water erosion pathways, and would greatly reduce leaching of contaminants to groundwater. Based on modeling results, this alternative is expected to reduce the mobility of the on-site contaminant to an extent that would result in an overall human health risk reduction (all pathways and all routes of exposure considered) of 79% and an overall ecological risk reduction of 91%.

8.7.5 Short-Term Effectiveness

It is anticipated that the construction phase of this alternative would be accomplished in a relatively short period of time (on construction season); therefore, impacts associated with construction would be short-term. Short-term impacts to the surrounding community are expected to be minimal because of the remote location of the project site and the lack of a resident population. However, short-term air quality impacts to the surrounding environment may occur. On-site workers would be adequately protected during the construction phase by utilizing appropriate personal protective equipment and by following proper operating and safety procedures. Control of fugitive dust emissions would be provided by applying water (via water truck) to surfaces receiving heavy vehicular traffic.

Under this alternative, wastes which are located directly in or near Frohner Meadows Creek, would be removed and/or recontoured to stabilize the creek channel. These construction activities would occur directly in or very near the current stream channel and may cause significant short-term adverse impacts to the water quality in the creek. For these reasons the creek would temporarily be diverted away from construction areas as needed to minimize short-term impacts. Stormwater run-off from other general construction activities may also cause short-term adverse impacts to water quality in the creek. Traditional construction BMPs would be employed to address these sources, and can effectively reduce adverse impacts on surface water from the construction activities.

8.7.6 Implementability

This alternative is both technically and administratively feasible, and could be implemented in a relatively short period of time (one construction season). The excavation, consolidation, grading, capping, and revegetation steps required are considered conventional construction practices; materials and construction methods are readily available. Also, design methods and requirements are well documented and well understood. However, the construction steps required to implement this alternative are considered moderately difficult (due, in part, to the rough terrain, potentially complex construction sequencing, and the remote location), and should only be performed by experienced contractors utilizing the appropriate equipment.

8.7.7 Costs

The total present worth cost for Alternative 5a has been estimated at $489,019, which represents the remediation of all solid media contaminant sources at the Frohner Mine and Millsite. Table C-5 (Appendix C) presents the cost details associated with implementing this alternative.

8.8 ALTERNATIVE 5b: PARTIAL REMOVAL TO ON-SITE REPOSITORY WITH CAP

Alternative 5b consists of in-place containment of some of the waste sources (WR1 through WR6) and complete removal of wastes located near Frohner Meadows Creek (WR7, TP1, and SSTs) to a repository. The repository would entail a multi-layered cap with no bottom liner.

8.8.1 Overall Protection of Human Health and the Environment

This alternative would provide a means of reducing soil ingestion exposure to the CoCs and would stabilize the surfaces of the primary sources with respect to migration to surface water. The reduction in risk to human health and the environment would not be sufficient to achieve the risk reductions dictated by the risk assessment. Alternative 5b would sufficiently reduce the migration of contaminants to surface water, and provides significant but insufficient reduction of soil and groundwater ingestion exposures.

Some protection of human health would be achieved under this alternative. Reduction of human exposures to CoCs via the pathways of concern, as identified in the human health risk assessment, would occur. Soil ingestion exposure to As and Pb via contaminated surface soil would be reduced, but neither would be reduced enough to meet the residential risk reduction levels; Pb would be reduced enough to meet the recreational risk levels, but As would not.

Limited protection of the environment would also be achieved under this alternative. Reduction of most ecologic exposures, via the scenarios identified in the ecologic risk assessment, would not occur: plant phytotoxicity to As and Pb would not be sufficiently reduced.

A risk reduction achievement matrix (Table 8-13) was developed to assess whether the alternative affords sufficient protection to human health and the environment for the pathways and CoCs identified in the human health risk assessment (Section 5.1) and the ecological risk assessment (Section 5.2). The conclusions presented in the table are based on worst-case modeling results subject to the limitations and assumptions used in the models (see Section 8.1 for discussion).

TABLE 8-13
RISK REDUCTION ACHIEVEMENT MATRIX FOR ALTERNATIVE 5b

ALTERNATIVE 5b	As	Cd	Cu	Pb	Zn	OVERALL
Human Health Exposure Pathways:						
Soil Ingestion	None	Res.	Res.	Recr.	Res.	None
Water Ingestion	Res.	Res.	Res.	Recr.	Res.	Recr.
Ecologic Exposure Pathways:						
Surface Water	--	Yes	--	--	Yes	Yes
Sediments	Yes	--	--	Yes	Yes	Yes
Plant Phytotoxicity	No	--	--	No	--	No

-- = Risk reduction not required for the contaminant for that pathway.
None = Does not achieve required risk reduction for any exposure scenario.
Recr. = Achieves required risk reduction for the recreational exposure scenario.
Res. = Achieves required risk reduction for the residential exposure scenario (most protective).

8.8.2 Compliance with ARARs

There are no ARARs that are required to be met for contaminated solid media. (One water quality ARAR is not expected to be achieved by this alternative.) A water quality ARARs attainment matrix (Table 8-14) was developed to assess whether the alternative can achieve ARARs for those contaminants and media where they are exceeded. The conclusions presented in the table are based on worst-case modeling results subject to the limitations and assumptions used in the models (see Section 8.1 for discussion).

TABLE 8-14
WATER QUALITY ARARS ATTAINMENT FOR ALTERNATIVE 5b

ALTERNATIVE 5b	As	Cd	Cu	Pb	Zn
On-site Groundwater (µg/L)	2.3	0.05	NM	53	NM
On-site Surface water (µg/L)	12	0.3	1.2	4.4	44
On-site Groundwater ARARs	Yes	Yes	--	No	--
On-site Surface Water ARARs	Yes	Yes	Yes	Yes	Yes

Groundwater ARARs are State HHSs.
Surface water ARARs are State HHSs or Acute AWQC, whichever is lower.
NM = Contaminant not modeled (Cu and Zn not included in TCLP suite).

On-site groundwater would not meet water quality ARARs for Pb. On-site surface water would meet water quality ARARs (Acute AWQCs).

8.8.3 Long-Term Effectiveness and Permanence

Under this alternative, waste rock dumps WR1 through WR6 will be graded, capped with cover soils and revegetated. The revegetated caps would stabilize these sources by providing an erosion-resistant, vegetated surface that would provide protection from surface water and wind erosion, and would reduce net infiltration through the contaminated media by increasing evapotranspiration processes. Run-on controls and grading would reduce infiltration by directing upgradient flows around the area, as well as by eliminating ponding and promoting run-off from the caps. The caps and run-on controls would have to be maintained to ensure that they perform as designed and consequently, long-term monitoring and frequent inspection and maintenance would be required. The caps would be susceptible to possible settlement, erosion, and disruption of cover integrity by vehicles, deep-rooting vegetation, and burrowing animals. However, the cover could be easily inspected and the required maintenance could be easily determined.

The cover soils and revegetation would consequently reduce the threat of direct contact and inhalation of airborne contaminant by on-site and nearby receptors. The long-term effectiveness of the cap would be enhanced by carefully determining proper amendments, and selecting appropriate plant species, adapted to short growing seasons and high altitudes (as opposed to selecting natives species exclusively).

The constructed repository would have to be maintained to ensure that it continues to perform as designed. The actual design life of the repository is not certain, and consequently, long-term monitoring and routine inspection and maintenance would be required. The repository cap would likely be the component most vulnerable to any damage or degradation that might occur. Multi-layered caps are susceptible to settlement, ponding of surface water, erosion, and disruption of cover integrity by vehicles, deep-rooting vegetation, and burrowing animals. However, the cap could easily be inspected and the required maintenance could be easily determined and performed. The composite cap would effectively isolate the waste materials and consequently reduce the threat of direct contact and inhalation of airborne contaminant by on-site and nearby receptors. The long-term effectiveness of the cap would be enhanced by carefully determining proper amendments, and selecting appropriate plant species, adapted to short growing seasons and high altitudes (as opposed to selecting natives species exclusively).

Run-on controls and proper grading would reduce infiltration by directing upgradient flows around the repository, as well as by eliminating ponding and promoting run-off from the cap.

In the long-term, the water quality and sediment environment (benthic community) in Frohner Meadows Creek are expected to be improved by implementing this alternative. Also, the downstream wetland and fishery is expected to benefit because the contaminant sources potentially impacting the stream would be stabilized with respect to surface water erosion. The long-term effectiveness should be monitored by frequent inspections of the capped/reclaimed wastes (subsequent maintenance should be performed when necessary) and extended surface water and sediment monitoring in Frohner Meadows Creek.

8.8.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The primary objective of this alternative is to provide a significant reduction in contaminant mobility: the volume or toxicity of the contaminant would not be reduced by implementing this alternative. The primary waste sources would be rendered immobile in an engineered facility, which is protected from erosion problems. The engineered facility would eliminate the direct contact and surface water erosion pathways, and would greatly reduce leaching of contaminants to groundwater. Based on modeling results, this alternative is expected to reduce the mobility of the on-site contaminant to an extent that would result in an overall human health risk reduction (all pathways and all routes of exposure considered) of 79% and an overall ecological risk reduction of 91%.

8.8.5 Short-Term Effectiveness

It is anticipated that the construction phase of this alternative would be accomplished in a relatively short period of time (on construction season). Therefore, impacts associated with construction would be short-term. Short-term impacts to the surrounding community are expected to be minimal because of the remote location of the project site and the lack of a resident population. However, short-term air quality impacts to the surrounding environment may occur. On-site workers would be adequately protected during the construction phase by utilizing appropriate personal protective equipment and by following proper operating and safety procedures. Control of fugitive dust emissions would be provided by applying water (via water truck) to surfaces receiving heavy vehicular traffic.

Under this alternative, wastes which are located directly in or near Frohner Meadows Creek, would be removed and/or recontoured to stabilize the creek channel. These construction activities would occur directly in or very near the current stream channel and may cause significant short-term adverse impacts to the water quality in the creek. For these reasons the creek would temporarily be diverted away from construction areas as needed to minimize short-term impacts. Stormwater run-off from other general construction activities may also cause short-term adverse impacts to water quality in the creek. Traditional construction BMPs would be employed to address these sources, and can effectively reduce adverse impacts on surface water from the construction activities.

8.8.6 Implementability

This alternative is both technically and administratively feasible, and could be implemented in a relatively short period of time (one construction season). The excavation, consolidation, grading, capping, and revegetation steps required are considered conventional construction practices; materials and construction methods are readily available. Also, design methods and requirements are well documented and well understood. However, the construction steps required to implement this alternative are considered moderately difficult (due, in part, to the rough terrain, potentially complex construction sequencing, and the remote location), and should only be performed by experienced contractors utilizing the appropriate equipment.

8.8.7 Costs

The total present worth cost for Alternative 5b has been estimated at $430,754, which represents the remediation of all solid media contaminant sources at the Frohner Mine and Millsite. Table C-6 (Appendix C) presents the cost details associated with implementing this alternative.

8.9 ALTERNATIVE 5c: PARTIAL REMOVAL TO ONSITE REPOSITORY WITH CAP

Alternative 5c consists of in-place containment of some of the waste sources (WR1, WR2, WR4, WR5, and WR6) present at the site, as well as completely removing all wastes which fail TCLP analyses (WR3, WR7, TP1, and SSTs) and moving them to the repository identified in Alternative 4. The repository design for this alternative consists of a multi-layered cap with no bottom liner. Figure 7-5 illustrates the conceptual cross-section showing the cap features.

8.9.1 Overall Protection of Human Health and the Environment

This alternative would provide a means of reducing soil ingestion exposure to the CoCs and would stabilize the surfaces of the primary sources with respect to migration to surface water. The reduction in risk to human health and the environment would not be sufficient to achieve all of the risk reductions dictated by the risk assessment. Alternative 5c would sufficiently reduce the migration of contaminants to surface water, and provides significant but insufficient reduction of soil and groundwater ingestion exposures.

Some protection of human health would be achieved under this alternative. Reduction of human exposures to CoCs via the pathways of concern, as identified in the human health risk assessment, would occur. Soil ingestion exposure to As and Pb via contaminated surface soil would be reduced, but As would not be reduced enough to meet the residential risk reduction levels; As would be reduced enough to meet the recreational risk level.

Limited protection of the environment would also be achieved under this alternative. Reduction of most ecologic exposures, via the scenarios identified in the ecologic risk assessment, would occur however, plant phytotoxicity to As would not be sufficiently reduced.

A risk reduction achievement matrix (Table 8-15) was developed to assess whether the alternative affords sufficient protection to human health and the environment for the pathways and CoCs identified in the human health risk assessment (Section 5.1) and the ecological risk assessment (Section 5.2). The conclusions presented in the table are based on worst-case modeling results subject to the limitations and assumptions used in the models (see Section 8.1 for discussion).

TABLE 8-15
RISK REDUCTION ACHIEVEMENT MATRIX FOR ALTERNATIVE 5c

ALTERNATIVE 5c	As	Cd	Cu	Pb	Zn	OVERALL
Human Health Exposure Pathways:						
Soil Ingestion	Recr.	Res.	Res.	Res.	Res.	Recr.
Water Ingestion	Res.	Res.	Res.	Recr.	Res.	Recr.
Ecologic Exposure Pathways:						
Surface Water	--	Yes	--	--	Yes	Yes
Sediments	Yes	--	--	Yes	Yes	Yes
Plant Phytotoxicity	No	--	--	Yes	--	No

-- = Risk reduction not required for the contaminant for that pathway.
None = Does not achieve required risk reduction for any exposure scenario.
Recr. = Achieves required risk reduction for the recreational exposure scenario.
Res. = Achieves required risk reduction for the residential exposure scenario (most protective).

8.9.2 Compliance with ARARs

There are no ARARs that are required to be met for contaminated solid media. One water quality ARARs is not expected to be achieved by this alternative. A water quality ARARs attainment matrix (Table 8-16) was developed to assess whether the alternative can achieve ARARs for those contaminants and media where they are exceeded. The conclusions presented in the table are based on worst-case modeling results subject to the limitations and assumptions used in the models (see Section 8.1 for discussion).

TABLE 8-16
WATER QUALITY ARARS ATTAINMENT FOR ALTERNATIVE 5c

ALTERNATIVE 5c	As	Cd	Cu	Pb	Zn
Onsite Groundwater (ug/L)	2.2	0.05	NM	27	NM
Onsite Surface water (ug/L)	12	0.3	1.2	4.2	42
Onsite Groundwater ARARs	Yes	Yes	--	No	--
Onsite Surface Water ARARs	Yes	Yes	Yes	Yes	Yes

Groundwater ARARs are State HHSs.
Surface water ARARs are State HHSs or Acute AWQC, whichever is lower.
NM = Contaminant not modeled (Cu and Zn not included in TCLP suite).

Onsite groundwater would not meet water quality ARARs for Pb. Onsite surface water would meet water quality ARARs (Acute AWQCs).

8.9.3 Long-Term Effectiveness and Permanence

Under this alternative, waste rock dumps WR1, WR2, WR4, WR5, and WR6 will be graded, capped with cover soils and revegetated. The revegetated caps would stabilize these sources by providing an erosion-resistant, vegetated surface that would provide protection from surface water and wind erosion, and would reduce net infiltration through the contaminated media by increasing evapotranspiration processes. Run-on controls and grading would reduce infiltration by directing upgradient flows around the area, as well as by eliminating ponding and promoting run-off from the caps. The caps and run-on controls would have to be maintained to ensure that they perform as designed and consequently, long-term monitoring and frequent inspection and maintenance would be required. The caps would be susceptible to possible settlement, erosion, and disruption of cover integrity by vehicles, deep-rooting vegetation, and burrowing animals. However, the cover could be easily inspected and the required maintenance could be easily determined.

The cover soils and revegetation would consequently reduce the threat of direct contact and inhalation of airborne contaminant by on-site and nearby receptors. The long-term effectiveness of the cap would be enhanced by carefully determining proper amendments, and selecting appropriate plant species, adapted to short growing seasons and high altitudes (as opposed to selecting natives species exclusively).

The constructed repository would have to be maintained to ensure that it continues to perform as designed. The actual design life of the repository is not certain, and consequently, long-term monitoring and routine inspection and maintenance would be required. The repository cap would likely be the component most vulnerable to any damage or degradation that might occur. Multi-layered caps are susceptible to settlement, ponding of surface water, erosion, and disruption of cover integrity by vehicles, deep-rooting vegetation, and burrowing animals. However, the cap could easily be inspected and the required maintenance could be easily determined and performed. The composite cap would effectively isolate the waste materials and consequently reduce the threat of direct contact and inhalation of airborne contaminant by on-site and nearby receptors. The long-term effectiveness of the cap would be enhanced by carefully determining proper amendments, and selecting appropriate plant species, adapted to short growing seasons and high altitudes (as opposed to selecting natives species exclusively).

Run-on controls and proper grading would reduce infiltration by directing upgradient flows around the repository, as well as by eliminating ponding and promoting run-off from the cap.

In the long-term, the water quality and sediment environment (benthic community) in Frohner Meadows Creek are expected to be improved by implementing this alternative. Also, the downstream wetland and fishery is expected to benefit because the contaminant sources potentially impacting the stream would be stabilized with respect to surface water erosion. The long-term effectiveness should be monitored by frequent inspections of the capped/reclaimed wastes (subsequent maintenance should be performed when necessary) and extended surface water and sediment monitoring in Frohner Meadows Creek.

8.9.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The primary objective of this alternative is to provide a significant reduction in contaminant mobility: the volume or toxicity of the contaminant would not be reduced by implementing this alternative. The primary waste sources would be rendered immobile in an engineered facility, which is protected from erosion problems. The engineered facility would eliminate the direct contact and surface water erosion pathways, and would greatly reduce leaching of contaminants to groundwater. Based on modeling results, this alternative is expected to reduce the mobility of the on-site contaminant to an extent that would result in an overall human health risk reduction (all pathways and all routes of exposure considered) of 98% and an overall ecological risk reduction of 98%.

8.9.5 Short-Term Effectiveness

It is anticipated that the construction phase of this alternative would be accomplished in a relatively short period of time (on construction season). Therefore, impacts associated with construction would be short-term. Short-term impacts to the surrounding community are expected to be minimal because of the remote location of the project site and the lack of a resident population. However, short-term air quality impacts to the surrounding environment may occur. On-site workers would be adequately protected during the construction phase by utilizing appropriate personal protective equipment and by following proper operating and safety procedures. Control of fugitive dust emissions would be provided by applying water (via water truck) to surfaces receiving heavy vehicular traffic.

Under this alternative, wastes which are located directly in or near Frohner Meadows Creek, would be removed and/or recontoured to stabilize the creek channel. These construction activities would occur directly in or very near the current stream channel and may cause significant short-term adverse impacts to the water quality in the creek. For these reasons the creek would temporarily be diverted away from construction areas as needed to minimize short-term impacts. Stormwater run-off from other general construction activities may also cause short-term adverse impacts to water quality in the creek. Traditional construction BMPs would be employed to address these sources, and can effectively reduce adverse impacts on surface water from the construction activities.

8.9.6 Implementability

This alternative is both technically and administratively feasible, and could be implemented in a relatively short period of time (one construction season). The excavation, consolidation, grading, capping, and revegetation steps required are considered conventional construction practices; materials and construction methods are readily available. Also, design methods and requirements are well documented and well understood. However, the construction steps required to implement this alternative are considered moderately difficult (due, in part, to the rough terrain, potentially complex construction sequencing, and the remote location), and should only be performed by experienced contractors utilizing the appropriate equipment.

8.9.7 Costs

The total present worth cost for Alternative 5c has been estimated at $426,334 which represents the remediation of all solid media contaminant sources at the Frohner Mine and Millsite. Table C-7 (Appendix C) presents the cost details associated with implementing this alternative.

8.10 ALTERNATIVE 6: OFF-SITE DISPOSAL – LUTTRELL PIT

Alternative 6 consists of excavating and disposing of all solid waste material from the Frohner Mine and Millsite in an existing mine waste repository located at the Luttrell Pit (Figure 7-6).

8.10.1 Overall Protection of Human Health and the Environment

This alternative would provide a means of almost completely reducing soil ingestion exposure to the CoCs and would stabilize the surfaces of the sources with respect to migration to surface water.

Protection of human health would be achieved under this alternative. Reduction of human exposures to CoCs via the pathways of concern, as identified in the human health risk assessment, would occur.

Protection of the environment would also be achieved under this alternative. Reduction of ecologic exposures, via the scenarios identified in the ecologic risk assessment, would occur.

A risk reduction achievement matrix (Table 8-17) was developed to assess whether the alternative affords sufficient protection to human health and the environment for the pathways and CoCs identified in the human health risk assessment (Section 5.1) and the ecological risk assessment (Section 5.2). The conclusions presented in the table are based on worst-case modeling results subject to the limitations and assumptions used in the models (see Section 8.1 for discussion).

TABLE 8-17
RISK REDUCTION ACHIEVEMENT MATRIX FOR ALTERNATIVE 6

ALTERNATIVE 6	As	Cd	Cu	Pb	Zn	OVERALL
Human Health Exposure Pathways:						
Soil Ingestion	Res.	Res.	Res.	Res.	Res.	Res.
Water Ingestion	Res.	Res.	Res.	Res.	Res.	Res.
Ecologic Exposure Pathways:						
Surface Water	--	Yes	--	--	Yes	Yes
Sediments	Yes	--	--	Yes	Yes	Yes
Plant Phytotoxicity	Yes	--	--	Yes	--	Yes

-- = Risk reduction not required for the contaminant for that pathway.
None = Does not achieve required risk reduction for any exposure scenario.
Recr. = Achieves required risk reduction for the recreational exposure scenario.
Res. = Achieves required risk reduction for the residential exposure scenario (most protective).

8.10.2 Compliance with ARARs

There are no ARARs that are required to be met for contaminated solid media. Water quality ARARs are expected to be achieved by this alternative. A water quality ARARs attainment matrix (Table 8-18) was developed to assess whether the alternative can achieve ARARs for those contaminants and media where they are exceeded. The conclusions presented in the table are based on worst-case modeling results subject to the limitations and assumptions used in the models (see Section 8.1 for discussion).

TABLE 8-18
WATER QUALITY ARARS ATTAINMENT FOR ALTERNATIVE 6

ALTERNATIVE 6	As	Cd	Cu	Pb	Zn
On-site Groundwater (μg/L)	2.0	0.04	NM	0.6	NM
On-site Surface water (μg/L)	2.0	0.07	1.5	1.2	9.7
On-site Groundwater ARARs	Yes	Yes	--	Yes	--
On-site Surface Water ARARs	Yes	Yes	Yes	Yes	Yes

Groundwater ARARs are State HHSs.
Surface water ARARs are State HHSs or Acute AWQC, whichever is lower.
NM = Contaminant not modeled (Cu and Zn not included in TCLP suite).

On-site groundwater would meet water quality ARARs. On-site surface water would also meet water quality ARARs (Acute AWQCs).

8.10.3 Long-Term Effectiveness and Permanence

Under this alternative, all of the waste sources would be completely removed, transferred to a different physical location, and managed under established regulatory programs and accepted waste management practice to ensure continued effectiveness. Removal of these waste sources would significantly reduce threats of exposure at the site. Revegetation of the residual disturbed soils/waste rock areas would further reduce the potential for exposure. After the removal is completed, the excavated areas would be revegetated, and consequently, the site problems associated with the solid media are expected to be permanently corrected.

8.10.4 Reduction of Toxicity, Mobility, of Volume Through Treatment

The implementation of these alternatives would result in eliminating the effects of toxicity, mobility, and volume from the site itself. Furthermore, contaminant mobility would be reduced through disposal in an engineered repository. Also, the waste would be permanently transferred to a different physical location where it can be managed under established regulatory programs to ensure continued effectiveness. Overall, the effects of toxicity, mobility, and volume of the wastes would be reduced to such an extent that this alternative would result in an overall human health risk reduction of 100% and an overall ecologic risk reduction of 98%.

8.10.5 Short-Term Effectiveness

It is anticipated that the construction phase of this alternative would be accomplished in a relatively short period of time (on construction season). Therefore, impacts associated with construction would be short-term. Short-term impacts to the surrounding community are expected to be minimal because of the remote location of the project site and the lack of a resident population. However, short-term air quality impacts to the surrounding environment may occur. On-site workers would be adequately protected during the construction phase by utilizing appropriate personal protective equipment and by following proper operating and safety procedures. Control of fugitive dust emissions would be provided by applying water (via water truck) to surfaces receiving heavy vehicular traffic.

Under this alternative, wastes which are located directly in or near Frohner Meadows Creek, would be removed and/or recontoured to stabilize the creek channel. These construction activities would occur directly in or very near the current stream channel and may cause significant short-term adverse impacts to the water quality in the creek. For these reasons the creek would temporarily be diverted away from construction areas as needed to minimize short-term impacts. Stormwater run-off from other general construction activities may also cause short-term adverse impacts to water quality in the creek. Traditional construction BMPs would be employed to address these sources, and can effectively reduce adverse impacts on surface water from the construction activities.

8.10.6 Implementability

This alternative is both technically and administratively feasible, and could be implemented in a relatively short period of time (one construction season). The excavation, consolidation, grading, capping, and revegetation steps required are considered conventional construction practices; materials and construction methods are readily available. Also, design methods and requirements are well documented and well understood. However, the construction steps required to implement this alternative are considered moderately difficult (due, in part, to the rough terrain, potentially complex construction sequencing, and the remote location), and should only be performed by experienced contractors utilizing the appropriate equipment.

8.10.7 Costs

The total present worth cost for Alternative 6 has been estimated at $644,860, which represents the remediation of all solid media contaminant sources at the Frohner Mine and Millsite. Table C-8 (Appendix C) presents the cost details associated with implementing this alternative.

9.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section provides a comparison of the solid media reclamation alternatives retained for the Frohner Mine Site. The comparison focuses mainly on the following criteria: 1) the relative protectiveness of human health and the environment provided by the alternatives; 2) the long-term effectiveness provided by the alternatives; and 3) the estimated attainment of ARARs for each alternative. Modeling results are used in the comparisons to contrast the two threshold criteria of "overall protection of human health and the environment" and "compliance with ARARs" for each alternative. The primary balancing criteria are also compared; although the evaluation of each of these criteria is very similar due to the technical similarities in the alternatives themselves, with the exception of costs. Table 9-1 presents a summary of the alternatives for the Frohner Mine with respect to the first seven evaluation criteria.

Of the alternatives retained for the site, Alternatives 4a, 4b, 5c, and 6 provide the greatest overall protectiveness of human health and the environment. These alternatives are expected to achieve compliance with action- and location-specific ARARs, including all groundwater and surface water quality ARARs; onsite groundwater is not predicted to meet water quality ARARs for Pb under alternatives 4b and 5c. Alternative 4a involves removing all wastes and disposing of them on-site in a modified RCRA repository (bottom liner and multi-layered cap) and provides a 100% human health risk reduction and a 98% reduction in the ecological risk. Alternative 4b involves removing all wastes and disposing of them on-site in a modified RCRA C repository (no bottom liner and multi-layered cap) and provides a 99% human health risk reduction and a 98% reduction in the ecological risk. Alternative 5c involves removing all hazardous waste (those failing TCLP) and disposing of them onsite in a modified RCRA repository (multi-layered cap with no bottom liner). This provides 98% risk reduction for both human health and ecologic risk. Alternative 6 involves removal of all wastes to an off-site repository and achieves 100% human health risk reduction and 98% reduction in the ecological risk.

Alternatives 3a, 3b, 5a, and 5b are expected to satisfy action- and location-specific ARARs and surface water ARARs, but are not predicted to satisfy groundwater ARARs by not meeting the HHS for Pb in groundwater. Alternatives 4a and 6 are the only alternatives that are predicted to meet the HHS for Pb in groundwater. These two alternatives are more protective than Alternatives 3a, 3b, 4b, 5a, and 5b, but are much more costly than the other action alternatives. Comparison of Alternative 1 (no action) to the other alternatives shows no net reduction in risk provided, as well as non-attainment of several ARARs.

The wastes would not be treated to reduce contaminant volume or toxicity under any of the alternatives evaluated in detail; only mobility would be reduced. Under Alternative 6, some of the wastes (many of which failed the TCLP test) may need to be treated prior to disposal. However, this alternative was determined to be cost prohibitive and may have been difficult to implement administratively, and many of the costs could not be determined. All of the alternatives (except the no action alternative) would provide varying degrees of reduction in contaminant mobility.

The short-term effectiveness is expected to be similar for each of the action alternatives. The alternatives are all technically similar, and the construction steps required to implement them would be similar as well. It is anticipated that any of the action alternatives could be completed in a single construction season. All alternatives may have short-term impacts on residents or recreational users of the forest in the vicinity because of the need for road access improvements and the need for imported materials.

The implementability of most alternatives is expected to be similar. All alternatives use conventional design and construction techniques. Alternative 6 may be administratively infeasible to implement because of the extensive administrative requirements (not fully defined) affiliated with the Luttrell Pit Central Mine Waste Repository.

For ease of construction, Alternatives 3a and 3b would probably be the easiest to implement because most of the wastes would be recontoured and reclaimed in-place, only requiring removal of WR7, TP1, and SSTs. However, it may be difficult to obtain suitable slopes and to establish vegetation on the regraded dumps. Alternatives 4a and 4b represent moderate technical difficulty because all wastes at the site would be excavated, loaded out, and transported to the repository area and would likely be the most difficult to implement. All alternatives would require the import of a considerable amount of lime, compost, and cover soils: availability of these materials and scheduling of delivery may make any action alternative somewhat difficult to implement.

Due to the large-scale nature of this reclamation project, in conjunction with the technical requirements applicable to constructing diversions, sedimentation basins, dewatering structures, and possibly repositories, only properly trained and experienced contractors/crews utilizing large-capacity equipment should perform the specified work. Small capacity equipment and/or inexperienced contractors and crews would likely prolong the construction phase and may result in increased costs and compromised performance.

Table 9-1 indicates the estimated total costs associated with each action alternative evaluated in detail. Of the various action alternatives considered for the site, Alternative 3a is the least costly, and Alternative 6 is the most costly. Although Alternatives 3a and 3b are the least costly, the estimated residual risks are not predicted to meet residential (3a does not meet recreational levels, while 3b does), though 3b reduces risk more than 5a or 5b, all of which meet the recreational level.

Alternative 4a provides slightly higher risk reduction than does Alternative 5c at a much higher cost; Alternative 5c provides a 98% human health risk reduction and a 98% reduction in the ecological risk, while Alternative 4a provides 100% human health risk reduction and 98% reduction in the ecological risk. Only Alternative 4a and 6 will satisfy all ARARs and provide the greatest reduction in risks. It may not be necessary to incur the additional cost associated with Alternative 4a because Alternative 5c meets all ARARs except modeled Pb in groundwater.

Alternatives 5a and 5b also meet all ARARs, except the Pb HHS standard in modeled groundwater at the site, and are much less expensive than Alternative 4a, but are less protective and more costly than 3b. Alternative 5b is more attractive than Alternative 5a because they both isolate the highest risk wastes in an engineered facility, but 5b (without a liner) is less costly and nearly as effective at risk reduction. Alternative 5c is more attractive than either Alternative 5a or 5b because although it isolates more of the highest risk wastes in an engineered facility, and is therefore more costly, Alternative 5c is much more effective at total risk reduction. The groundwater downgradient of the site is not currently used for drinking water, and given the much higher cost of Alternatives 4a and 6, it may be appropriate to accept the residual (modeled) risk associated with Alternative 5c. Table 9-2 summarizes the estimated cost per unit risk reduction for each action alternative.

Table 9-2 indicates Alternatives 3a and 3b provide the best risk reduction per unit cost of all the action alternatives. However, only Alternative 3b even approaches the required risk reduction dictated by the risk assessment. Alternative 5c achieves greater risk reduction while having essentially the same risk reduction per unit cost.

TABLE 9-2
ALTERNATIVE COST-EFFECTIVENESS COMPARISON SUMMARY
FROHNER MINE SITE

ALTERNATIVE	OVERALL HUMAN HEALTH RISK REDUCTION (HH)	OVERALL ECOLOGIC RISK REDUCTION (E)	TOTAL PRESENT WORTH VALUE	COST PER 1% REDUCTION IN HH RISK	COST PER 1% REDUCTION IN ECOLOGIC RISK
Alternative 3a	68%	88%	$305,288	$4,490	$3,469
Alternative 3b	90%	95%	$400,856	$4,454	$4,220
Alternative 4a	100%	98%	$651,506	$6,515	$6,648
Alternative 4b	99%	98%	$561,310	$5,670	$5,728
Alternative 5a	79%	91%	$489,019	$6,190	$5,374
Alternative 5b	79%	91%	$430,754	$5,453	$4,734
Alternative 5c	98%	98%	$417,661	$4,262	$4,262
Alternative 6*	100%	98%	$644,860	$6,449	$6,580

* May be administratively infeasible.

10.0 PREFERRED ALTERNATIVE

Based on the information provided in this report, Alternative 5c (partial in-place containment and partial removal to an on-site repository) is the preferred alternative for the solid media at the Frohner Mine Site.

Alternative 5c entails in-place containment of waste sources WR1, WR2, WR4, WR5, and WR6 (those not failing TCLP) and consolidation of waste sources WR3, WR7, TP1, and SSTs (those failing TCLP) to an engineered repository. The repository would consist of a multi-layered lined cap over the waste materials, but would not have a bottom liner or leachate collection system. The location of this repository has not been determined, and an investigation of candidate repository locations would have to be performed to assess suitability. The repository would cover approximately 0.5 acre and would contain approximately 10,200 cy of wastes.

For the purpose of this evaluation, the conceptual design for Alternative 5c includes removing WR3, WR7, TP1, and some streamside tailings from their current locations and disposing the wastes in the repository. Surface water diversions would be installed and a diversion constructed to direct mine water discharges away from reclaimed areas. Diversions would also be constructed to prevent run-on to reclaimed areas. Run-off diversions would be installed to prevent erosion and direct run-off in order to mitigate erosion from the site before vegetation is re-established. The stream channel would be reconstructed and armoring installed where wastes are removed from near the stream. Physical hazards (unstable slopes, open adits, and shafts) would be mitigated as a portion of the reclamation.

This alternative is projected to reduce overall risks to human health by 98% and ecologic risks by 98%. This alternative is predicted to attain all ARARs except for Pb in groundwater.

The following issues were considered when selecting this alternative:

- it provides satisfactory risk reduction at a reasonable cost;

- implementability of this alternative is expected to be simpler than other alternatives that provide comparable risk reductions (i.e., all wastes to a repository, off-site disposal); and

- the repository will effectively reduce contaminant mobility from the highest risk wastes at the site and consolidate them in a single location away from the creek and surface water conveyances.

Alternative 5c provides a comparable risk reduction to Alternatives 4a and 6 at a lower cost. However, because of implementability concerns (Alternative 6) and much greater costs (Alternatives 4a and 6), Alternative 5c is preferred over Alternatives 4a and 6. Therefore, Alternative 5c is the preferred alternative.

11.0 REFERENCES

DEQ/MWCB-Pioneer, 1999a. Draft Field Sampling Plan for the Frohner Mine Site Removal Action Investigation. Prepared for DEQ/MWCB by Pioneer Technical Services, Inc., November 1999.

DEQ/MWCB-Pioneer, 1999b. Draft Quality Assurance Project Plan for the Frohner Mine Site. Prepared for DEQ/MWCB by Pioneer Technical Services, Inc., November 1999.

DEQ/MWCB-Pioneer, 1998a. Reclamation Work Plan for the Frohner Mine Site. Prepared for the DEQ/MWCB by Pioneer Technical Services, Inc., 1998.

DEQ/MWCB-Pioneer, 1998b. Final Adit Baseline Characterization Investigation Report. Prepared for DEQ/MWCB by Pioneer Technical Services, Inc., February 1998.

DEQ/MWCB-Pioneer, 1995. Hazardous Materials Inventory Site Investigation Log Sheet for the Frohner Mine Site. Prepared for the DEQ/MWCB by Pioneer Technical Services, Inc., September 15, 1995.

DEQ/WQB, 1998. Montana Department of Environmental Quality/Water Quality Bureau. Montana Numeric Water Quality Standards, Circular WQB-7. July 1998.

EPA, 1990. U.S. Environmental Protection Agency. National Oil and Hazardous Substance Pollution Contingency Plan (NCP); Final Rule (40CFR 300). Federal Register 55(46): 8666-8865, March 8, 1990.

EPA, 1989a. U.S. Environmental Protection Agency. Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Interim Final). Office of Emergency and Remedial Response, Washington, D.C. EPA/540/1-89/002.

EPA, 1989b. U.S. Environmental Protection Agency. Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual (Interim Final). Office of Emergency and Remedial Response, Washington, D.C. EPA/540/1-89/001.

EPA, 1989c. U.S. Environmental Protection Agency. Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference. Environmental Research Laboratory, Corvallis, OR. EPA/600/3-89/013.

EPA, 1988. U.S. Environmental Protection Agency. Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (Interim Final). Office of Emergency and Remedial Response, Washington, D.C. EPA/540/G-89/004.

Kabata-Pendias and Pendias, 1989. Trace elements in soil and plants. CRC Press, Inc., Boca Raton, FL.

Long and Morgan, 1991. The potential for biological effects of sediment-sorbed contaminants tested in the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 52. National Oceanographic and Atmospheric Administration, Seattle, WA.

National Oceanic and Atmospheric Administration, 1995, Local climatological data, annual summary with comparative data.

Smith, 1995. Risk-Based Concentration Table, July-December, 1995. Prepared by USEPA, Region III, Office of RCRA, Technical Program Support Branch. Memorandum from Dr. Roy L. Smith dated October 20, 1995.

TetraTech, 1996. Risk-Based Cleanup Guidelines for Abandoned Mine Sites. Prepared for the Montana Department of Environmental Quality, Abandoned Mine Reclamation Bureau by Tetra Tech, Inc.

U.S. Geological Survey, 1986. Topographic Map of Chessman Reservoir, 7 ½ minute Quadrangle, 1986.